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Analysis of Blood, Hair, Urine, and Dust Samples for Heavy Metals

Stewart Labs, Inc, Knoxville, Tenn

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Health Effects Research Lab, Research Triangle Park, N C Population Studies Div

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ANALYSIS OF BLOOD, HAIR, URINE, AND DUST SAMPLES FOR HEAVY METALS

By

Anna M. Yoakum
Stewart Laboratories, Inc.
5815 Middlebrook Pike
Knoxville, TN 37921

Contract No. 68-02-2266

Project Officer

Dr. Carl Hayes
Population Studies Division
Health Effects Research Laboratory
Research Triangle Park, N.C. 27711

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
HEALTH EFFECTS RESEARCH LABORATORY
RESEARCH TRIANGLE PARK, N.C. 27711

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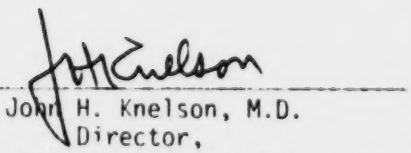
FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory develops and revises air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is preparing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

The chemical analyses provided under this contract support a collaborative survey by the Center for Disease Control and the Environmental Protection Agency to assess metal absorption in children living in the vicinity of primary non-ferrous smelters. The results of the overall survey will be reported separately.



John H. Knelson, M.D.
Director,
Health Effects Research Laboratory

ABSTRACT

Communities from ten states in the United States and two cities in Mexico were studied. The communities were chosen for their proximity to primary non-ferrous smelter industries.

Three lead and five zinc smelter areas were sampled for blood, hair, and dust. Urine, blood, hair, and dust were collected from fourteen copper smelter sites and four control cities.

Samples were analyzed for arsenic, lead, cadmium, copper and zinc.

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I. INTRODUCTION

Documentation of excessive absorption of heavy metals by children living near nonferrous metal smelters in the U. S. A. and Canada activated a nationwide study to determine the distribution of several heavy metals around primary lead, zinc, and copper smelters. Preschool children were selected as test subjects because signsof absorption of heavy metals are more likely to appear with them than with older children or adults. The purpose of this project was to analyze tissue and dust samples collected from test subjects living within a two mile radius of each smelter so that heavy metal absorption could be evaluated.

Control sites were selected to provide background reference data as to the existing level of these heavy metals in areas not associated with nonferrous smelters.

II. SUMMARY

The study encompassed collections from ten states in the U. S. A. and two cities in Mexico. Tissue and dust samples from preschool children and their homes were differentiated for analysis in accord with the type smelter or control being evaluated.

Three lead and five zinc smelter areas were sampled for blood, hair, and dust. Urine, blood, hair, and dust were collected from fourteen copper smelter sites and four control cities.

All dust samples were analyzed for As, Pb, Cd, Cu, and Zn. Hair samples from lead and zinc smelter sites were analyzed for Cd and Pb; while copper smelter sites and control areas received As, Pb, and Cd determinations. Urine collections (copper smelter sites and control areas) were measured for specific gravity and As. Lead and FEP were analyzed in blood from all three smelter types. Additionally, Cd was included for lead smelter sites; Cd and Zn for zinc smelter sites; and Cu and Zn for copper smelter sites. Control bloods were tested for all five blood parameters.

Internal and external quality control programs were integrated with sample analyses. Accuracy and precision data derived from these programs are reported and analyzed in depth.

Analyses for each collection site were reported in progressive order in accord with a numeric field assignment for individual subjects from

each participating family. The laboratory analyst and date for each determination, including quality controls, was shown within this format.

III. CONCLUSIONS

The quality of the analytical results produced during this study has been evaluated in terms of uncertainty measurements which represent at least 95 percent confidence interval based on measurement error and variability between samples. The detrimental effects contributed by the samples themselves were successfully overcome in all sample types except urine. Overall accuracy and precision, expressed as relative percent, for each sample category is as follows: dust, $\pm$ 3%, hair, $\pm$ 5%, blood, $\pm$ 10%, and urine, $\pm$ 49%.

IV. RECOMMENDATIONS

Based on the experience gained in the performance of this contract, the following recommendations are suggested for the improvement of future projects of a similar nature:

A. Dust - The smear technique employed in the collection of the dust samples has two significant shortcomings.

A sample of this type does not lend itself to any standard analytical quality control program. Since the entire sample cannot be removed, blind sample splits and recovery studies cannot be conducted.

Data obtained can be reported only in terms of micrograms of acid soluble metal per towelette (or per sample). Since the actual amount of sample collected varied widely, the ability to express the data as micrograms of metal per gram of dust would have allowed for an exact comparison of analytical data between collection sites, rather than the relative comparison which results from the method employed.

From a collection standpoint, dust is, perhaps, the most difficult sample type addressed in this project. Paint and other materials heavily laden with metals may be preferentially dissolved by the organic liquids in the towelettes. The abrasive nature of the sampling procedure contributes to the incorporation of these con-

taminants in the samples, and there is no procedure for obtaining an initial weight of the dust as it is collected.

A recommended dust collection technique, which the contractor has used, involves dusting a surface of sufficient size to render a sample adequate for complete analysis. A small camel's hair brush is used to sweep the sample into a small whirlpak. This disallows external contamination from the hands of field personnel, surface finishes, and/or the implement used for collection. The brush must, however, be thoroughly cleaned after each use.

B. Urine - In order to combat the tendency for urine samples to preferentially precipitate with time lapse and temperature variations, a change in the collection protocol would be necessary.

Specific gravity measurements should be performed in the field as each sample is collected.

Since time lapse and temperature variations occur during storage and transport to the laboratory, urine samples should be shaken and aliquoted in the field as soon after collection as possible. If blind splits are to be made, this should also be performed at that time. This procedure would allow for homogeneity of each sample, and it would assure uniform analytical handling.

C. Blood - Since clotted blood does not lend itself to uniform sample aliquoting techniques, two avenues are open as approaches to preclusion of this problem. First, sample splits could easily be made from the syringe while the blood is fresh and not clotted.

Secondly, a more uniform mixing with an anticoagulant could be applied. The former would, at this time, appear to be the safest and simplest.

All blood samples should be ejected from the syringe into containers appropriate for shipment. Inverted, leaky syringes held together with various types of tape do not constitute proper shipping vessels.

D. Hair - The extreme variation of metals content in hair indicates that small samples are not representative of the overall hair of the subject. Thus, a concerted effort should be made to collect as large a sample as possible from each subject.

Zip-loc bags provide excellent transport containers; however, they should be locked carefully as soon as they receive a sample of hair. A secure seal allows for transport in a condition isolated from external contamination. Each hair sample should be handled with gloves and completely enclosed within the plastic bag.

Human scalp hair is widely used for assessing environmental exposure to metals. Trace metal content of hair is, likewise, reported to be an indicator of deficiency conditions in both humans and test animals. Because of these considerations and because of the ready availability of hair as a biopsy tissue, scalp hair lends itself well to environmental monitoring of humans for trace metal exposure.

A number of problems are apparent which could have significant influence on the interpretation of data for hair as a valid

biological indicator for environmental exposure. Findings from a series of pilot research studies conducted by the contractor, as in-house satellite investigations, clearly indicate the need to conduct a more closely controlled investigation in the area of trace metal analysis of hair. There is, thus, a need for the design of an analytical study to define, investigate, and establish the parameters which can adversely influence the interpretation of hair data.

The recommended research should study, for a period of at least two years, the trace metal content of scalp hair samples collected under carefully controlled conditions from a healthy population living in an area free from major point source atmospheric metal contamination. All pertinent background information relating to the sampling population should be made available so that relationships between trace metal contents and personal covariants can be evaluated. This requires an extensive, well-administered questionnaire. Participation in the program should be limited to those subjects who are willing and cooperate fully in providing all pertinent background information to be included in the study; therefore, the selection of the sampling population should be carefully controlled to assure that all vital areas are included in the study.

Since factors other than environmental exposure can play a significant role in trace metal concentrations and distributions, the study should address itself to the following potential factors:

(1) Seasonal variations--i.e., hair growth rate and frequency of hair care.

(2) Hair care--i.e., types and frequency of use of chemical products and their contribution to elemental alteration of hair.

(3) Inherent variabilities--i.e., physical and physiological hair characteristics and metals content along single strands of hair.

(4) Time effects--i.e., storage time for washed versus unwashed hair prior to analysis.

(5) Participant characteristics--i.e., race, medical treatment, residence location, smoking habits, diet, sex, age, etc.

E. General Sampling Protocol - Consistency in adherence to a sampling protocol at each collection site is essential from a quality control standpoint. Certain basic guidelines should be followed in order to obtain data which can be compared directly and correlated with known varying parameters. These parameters should have been primarily limited to 1) geography, baseline conditions, and environmental exposure characteristics and 2) inherent biological uptake of heavy metals.

In order to produce data which represent a real profile of these conditions, one should properly and legibly code and permanently

label each sample as it is collected. Each individual sample should be treated precisely the same as all other samples of that particular type. The protocol should be realistic in terms of maximum time required to perform each field procedure. For example, frozen samples shipped over long distances should arrive, at the laboratory, in the same condition as those shipped from proximal collection sites.

Provided the recommended protocols for field sample procedures, as discussed for each sample type, are followed, all collections could be shipped directly to participating laboratories on an individual basis. This would eliminate variables such as time differentials, thawing of samples, inhomogenous aliquots, and misplacement of partial batches.

Also, uniformity of sample sizes submitted for analysis should be held at a reasonable tolerance level. All containers to be used in a project of this type should be procured from single line suppliers and, preferably, from a given manufacturing batch or lot.

Shipment schedules for submission of samples for analysis should be planned in advance and modes of transport carefully investigated.

A continuous rapport and conscientious use of quality control among persons responsible for field sampling, laboratory analyses, and project management are imperative in the obtainment of valid and useful analytical data.

V. DISCUSSION OF ANALYTICAL APPROACH AND RESULTS

A. Preliminary Treatment for Sample Preparation - This project included receipt of human tissue and house dust from twenty-four sampling sites. Of these sites, three were near lead smelters, five near zinc smelters, twelve near copper smelters, and four were from control areas (Table 1). Because of deviations from the prescribed sampling protocol, a laboratory screening of those samples not meeting the minimum requirements for analysis was established. The criteria on which samples were rejected are shown in Table 2. The acceptable size limits were prescribed in the contract; however, additional measurements were required in the laboratory in order to differentiate samples which were very near the limit and could not be visually determined. The various procedures for handling these samples will be discussed on an individual basis for each sample type, and the rejections made for each collection site will be enumerated and related to their cause.

1. Procedures for Sample Screening--Each shipment contained samples from several collection sites and, therefore, required a preliminary sorting and assignment to an organized sequence for analysis. Once this process had been achieved, each sample type was individually screened for analytical acceptability.

   a. Blood--The tubes were checked for cracks and/or probable contamination, and notations were recorded when appropriate. All samples which were not whole blood or could not be

Table 1. Breakdown of Samples Received Versus Samples Analyzed per Collection Site

SAMPLING AREA			SAMPLE COLLECTIONS							
			BLOOD		HAIR		URINE		DUST	
TYPE	LOCATION	CODE	RECEIVED	ANALYZED	RECEIVED	ANALYZED	RECEIVED	ANALYZED	RECEIVED	ANALYZED
Lead	Herculaneum, MO	HK	102	91	112	76			97	10
Lead	Bixby, MO	BX	50	48	59	20			40	10
Lead	Glover, MO	GL	35	23	37	30			31	10
Zinc	Bartlesville, OK	BV	90	87	95	80			65	10
Zinc	Corpus Christi, TX	CC	51	13	73	38			46*	0
Zinc	Monaca, PA	MN	65	63	78	65			0	0
Zinc	Palmerton, PA	PL	112	112	107	74			78	10
Zinc	Amarillo, TX	AM	97	95	92	40			52	10
Copper	Hayden, AZ	HA	99	99	109	105	92	84	69	10
Copper	Miami, AZ	MI	101	101	95	78	81	72	72	10
Copper	Morenci, AZ	MO	102	100	106	98	102	77	74	10
Copper	Ajo, AZ	AJ	107	107	101	86	78	78	69	10
Copper	Anaconda, MT	AN	70	65	87	87	75	42	57	10
Copper	McGill, NV	MG	52	51	64	47	53	49	45	10
Copper	San Manuel, AZ	SM	103	101	111	14	87	55	79	10
Copper	White Pines, MI	WP	72	71	86	81	68	59	84	10
Copper	Copper Hill, TN	CH	89	87	96	92	84	65	72	10
Copper	Douglas, AZ	DO	97	97	101	95	93	80	63	10
Copper	Agua Prieta, Mexico	AP	99	98	105	74	88	75	54	10
Copper	Hurley, NM	HL	51	49	95	94	76	57	74	10
Control	Safford, AZ	SA	97	93	109	53	97	62	75	10
Control	Perryville, MO	PV	86	86	102	86	99	81	76	10
Control	Albuquerque, NM	AL	85	83	101	23	73	51	78	10
Control	Nogales, Mexico	NG	106	106	114	67	104	97	79	10

* taken on cotton balls

TABLE 2. Criteria for Rejection of Samples from the Project.

Sample Tissue Type	Criteria for Rejection
Blood	< 1 ml not complete whole blood indeterminant code identification
Hair	< 0.2 gm indeterminant code identification
Urine	< 25 ml indeterminant code identification samples not contracted
Dust	taken on materials other than towelettes indeterminant code identification

identified from labels were counted and discarded. After thawing, the blood volumes were individually compared visually against a reference 1 ml blood sample. Those samples determined to be <1 ml were counted and discarded; however, because of excessive clotting and the large number of samples which were close to the 1 ml volume, some samples were processed and analyzed for FEP and later discarded for further analysis. This was done after the blood was transferred to a graduated cylinder for volumetric measurement. FEP determinations were made prior to this transfer because of the prescribed time requirement in the method. All blood samples which had been rejected were reassembled and enumeration checks were finalized.

b. Hair--Since hair and dust were frequently shipped in bags together, a separation and verification of code assignments of these samples was necessary prior to screening. Samples obviously too small and/or with unidentifiable labels were rejected. Improperly sealed bags were noted as were containers other than Zip-locs. A second screening of hair was attempted by weighing borderline samples on a top loading balance. If the weights were between 0.20 and 0.25 gm, the samples were reentered and coded for analysis. Some of these samples fell below the 0.2 gm limit when reweighed on an analytical balance after they had been cleaned and dried. These final discards were added to all of the hair previously rejected, and proper notations were recorded.

c. Urine--Some shipments contained urine from lead and zinc smelter sites, which were not to be included for analysis under this contract; therefore, these samples were rejected. Each of the samples included for analysis was compared, after thawing, to a reference urine of a 25 ml volume. All samples failing to meet this criterion were enumerated and rejected.

d. Dust--After separation from hair samples (see Hair above), dust was observed for adherence to sampling protocols and analytical preferences. Since only ten samples per collection site were to be chosen, properly sealed bags with no evidence of contamination received top consideration. Apparent sample size and legibility of label codes were then utilized as secondary criteria. One entire shipment of dust from Corpus Christi, Texas, was discarded because the samples had been taken on cotton balls and blanks were unavailable. Rejected dust samples were enumerated after all these selection criteria had been imposed.

2. Sample Conditions and Handling Techniques--The sample conditions and the various procedures for handling these samples are presented on an individual basis for each sample type according to collection site. A summary of samples received versus samples analyzed is given in Table 1.

a. Lead Smelters--The lead smelter samples were to be analyzed for: FEP, Pb, and Cd in blood; Pb and Cd in hair; and Pb,

Cd, Zn, Cu, and As in dust. Of the 187 bloods received, 162 were completely analyzed; of the 208 hair samples, 126 were completely analyzed; and of the 158 dust samples, the prescribed 30 were appropriate for complete analysis. The following is a resume of the condition of sample shipments and preliminary analytical treatment of samples received from each lead smelter.

HERCULANEUM, MO

General - Samples received 9/18/75 with no instructions therefore all samples initially coded

Blood - All thawed; 28 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd; 11 run for FEP only

Hair - Zip-locs sealed; 36 rejects

Urine - Received 108 not to be analyzed--all were coded

Dust - Zip-locs not sealed; 77 screened

BIXBY, MO

General - Samples received 9/25/75

Blood - Partially thawed; 2 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd

Hair - Zip-locs and sealed; 39 rejects

Urine - Samples received but not to be analyzed

Dust - Zip-locs and sealed; 30 screened

GLOVER, MO

General - Samples received 9/25/75

Blood - Partially thawed; 1 badly clotted therefore duplicate FEP run; condition required special mixing for Cd

Hair - Zip-locs and sealed; 7 rejects

Urine - Samples received but not to be analyzed

Dust - Zip-locs and sealed; 21 screened

b. Zinc Smelters - The zinc smelter samples were to be analyzed for FEP, Pb, Cd, and Zn in blood; Pb and Cd in hair; and Pb, Cd, Zn, Cu, and As in dust. Total analyses were completed for 370 of the 415 bloods received, 297 of the 445 hair samples, and 30 of the prescribed 50 from a total of 241 dust samples. A resume of each zinc smelter follows.

BARTLESVILLE, OK

General - Samples received 9/18/75 with no instructions therefore all samples initially coded

Blood - All thawed; all in inverted syringes; 13 with white adhesive tape, 59 with black electrical tape, 18 with scotch tape; 3 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd; 3 for FEP only

Hair - Alligator sandwich bags with twist ties; 15 rejects

Urine - Received 75 not to be analyzed--all were coded

Dust - Alligator sandwich bags with twist ties, towelettes very dry; 55 screened

CORPUS CHRISTI, TX

General - Samples received 11/18/75 and 11/20/75; all samples had to be re-coded from information received from CDC

Blood - Partially or completely thawed; received 51 samples. 38 of which were rejects because they had been spun down and only plasma separates were shipped; condition required special mixing for Cd on the 13 whole blood samples

Hair - Zip-locs sealed; 35 rejects

Urine - Samples received but not to be analyzed

Dust - Zip-locs sealed but all 46 were rejects because they had been taken on cotton balls instead of towelettes

MONACA, PA

General - Samples received 11/18/75, 12/5/75, and 12/16/75

Blood - First and second shipments partially thawed--third shipment (4) not iced at all; 31 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd; third shipment (4) received after coding, causing handling and data processing problems because of skips in numerical sequence

Hair - Zip-locs and sealed; 13 rejects

Urine - Samples received but not to be analyzed

Dust - No samples received

PALMERTON, PA

General - Samples received 1/9/76

Blood - Frozen; 2 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd

Hair - Zip-locs sealed; 33 rejects

Urine - Samples received but not to be analyzed

Dust - Zip-locs sealed; 68 screened

AMARILLO, TX

General - Samples received 1/9/76

Blood - Frozen; 1 badly clotted therefore duplicate FEP run; condition required special mixing for Cd

Hair - Zip-locs mostly sealed; 52 rejects

Urine - Samples received but not to be analyzed

Dust - Zip-locs mostly sealed; 42 screened

c. Copper Smelters - The copper smelter samples were to be analyzed for: FEP, Pb, Zn, and Cu in blood; Pb, Cd, and As in hair; specific gravity and As in urine; and Pb, Cd, Zn, Cu, and As in dust. Of the 1046 bloods received, 1026 were completely analyzed; of the 1156 hair samples, 951 were analyzed; of the 977 urines, 793 were analyzed; and of the 812 dust, the prescribed 120 were appropriate for complete analysis. A resume of each copper smelter follows.

HAYDEN, AZ

General - Samples received 9/18/75 with no instructions therefore all samples initially coded; all samples completely mixed with MI

Blood - Partially thawed; labels extremely difficult to read; 12 badly clotted therefore duplicate FEP's run

Hair - Zip-locs mostly not sealed; 4 rejects

Urine - Partially thawed; 8 rejects; precipitated

Dust - Zip-locs mostly not sealed; 59 screened

MIAMI, AZ

General - Samples received 9/18/75 with no instructions therefore all samples initially coded; all samples completely mixed with HA

Blood - Partially thawed; labels difficult to read; 18 badly clotted therefore duplicate FEP's run

Hair - Zip-locs mostly not sealed; 17 rejects

Urine - Partially thawed; 9 rejects; precipitated

Dust - Zip-locs mostly not sealed; 62 screened

MORENCI, AZ

General - Samples received 9/25/75

Blood - Partially thawed; 7 badly clotted therefore duplicate FEP's run

Hair - Zip-locs sealed; 8 rejects

Urine - Completely thawed; 25 rejects; heavily precipitated

Dust - Zip-locs sealed; 64 screened

AJO, AZ

General - Samples received 10/15/75 and 10/30/75

Blood - Partially thawed; 8 badly clotted therefore duplicate FEP's run

Hair - Zip-locs sealed; 15 rejects

Urine - Partially thawed; 9 rejects; precipitated; 6 samples received too late to run with scheduled batch

Dust - Zip-locs sealed; 59 screened

ANACONDA, MT

General - Samples received 10/30/75

Blood - Thawed; 3 badly clotted therefore duplicate FEP's run

Hair - Zip-locs mostly sealed

Urine - Partially thawed; 33 rejects; precipitated

Dust - Zip-locs mostly sealed; 47 screened

McGILL, NV

General - Samples received 10/30/75

Blood - Thawed; 4 badly clotted therefore duplicate FEP's run

Hair - Zip-locs mostly sealed; 17 rejects

Urine - Partially thawed; bad leakage in shipping container; 4 rejects; precipitated

Dust - Zip-locs mostly sealed; 35 screened

SAN MANUEL, AZ

General - Samples received 10/30/75

Blood - Thawed; 14 badly clotted therefore duplicate FEP's run; 29 samples sent in inverted syringes, untaped; tubes cracked and bad leakage on samples and container; codes very difficult to read

Hair - Zip-locs mostly sealed; 97 rejects

Urine - Thawed; slight leakage in container; 32 rejects; heavily precipitated

Dust - Zip-locs mostly sealed; 69 screened

WHITE PINES, MI

General - Samples received 11/18/75

Blood - Partially thawed; 1 badly clotted therefore duplicate FEP run; 1 FEP only

Hair - Zip-locs partially sealed or not sealed; bags contaminated with blood; 5 rejects

Urine - Partially thawed; codes very difficult to read; 9 rejects; precipitated

Dust - Zip-locs partially sealed or not sealed; bags contaminated with blood; 74 screened

COPPER HILL, TN

General - Samples received 11/18/75, 11/20/75, and 12/16/75

Blood - Partially or completely thawed; 12 badly clotted therefore duplicate FEP's run

Hair - Zip-locs sealed; 4 rejects

Urine - Partially or completely thawed; some codes very difficult to read; 19 rejects; heavily precipitated; 15 samples received too late to run with scheduled batch

Dust - Zip-locs sealed; 62 screened

DOUGLAS, AZ

General - Samples received 11/18/75 and 11/20/75

Blood - Partially thawed; 7 badly clotted therefore duplicate FEP's run

Hair - Zip-locs sealed; 6 rejects

Urine - Partially thawed; 13 rejects; precipitated

Dust - Zip-locs sealed; 53 screened

AQUA PRIETA, MEXICO

General - Samples received 11/18/75 and 11/20/75

Blood - Partially or completely thawed; 11 badly clotted therefore duplicate FEP's run

Hair - Zip-locs partially sealed or not sealed; 31 rejects

Urine - Partially or completely thawed; 13 rejects; heavily precipitated

Dust - Zip-locs partially sealed or not sealed; 44 screened

HURLEY, NM

General - Samples received 1/9/76

Blood - Frozen

Hair - Zip-locs sealed; 1 reject

Urine - Frozen; codes very difficult to read; 19 rejects; precipitated

Dust - Zip-locs sealed; 64 screened

d. Control Areas - The control samples were to be analyzed for: FEP, Pb, Cd, Zn, and Cu in blood; Pb, Cd, and As in hair; specific gravity and As in urine; and Pb, Cd, Zn, Cu, and As in dust. Complete analyses were achieved on 368 of the 374 bloods, 229 of the 426 hair samples, 291 of the 373 urines, and the 40 prescribed dust samples from a total of 308. The following is a resume of each control area:

SAFFORD, AZ

General - Samples received 12/5/75 and 12/16/75

Blood - First shipment frozen or partially thawed; second shipment (10) not iced at all; 11 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd; second shipment (10) received after coding, causing handling and data processing problems because of skips in numerical sequence

Hair - Zip-locs sealed; 56 rejects

Urine - Partially thawed; 35 rejects; precipitated

Dust - Zip-locs sealed; 65 screened

PERRYVILLE, MO

General - Samples received 12/5/75 and 12/16/75

Blood - First shipment frozen or partially thawed; second shipment (9) not iced at all; 5 badly clotted therefore duplicate FEP's run; conditions required special mixing for Cd; second shipment (9) received after coding, causing handling and data processing problems because of skips in numerical sequence

Hair - Zip-locs sealed; 16 rejects

Urine - Partially thawed; 18 rejects; precipitated

Dust - Zip-locs sealed; 66 screened

ALBUQUERQUE, NM

General - Samples received 12/5/75 and 12/16/75; all samples not properly labeled--lacked child code, sent coding sheets to CDC for corrections

Blood - First shipment frozen or partially thawed; second shipment (9) not iced at all; 7 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd; second shipment (9) received after coding, causing handling and data processing problems because of skips in numerical sequence

Hair - Zip-locs not sealed; 78 rejects

Urine - Thawed; 22 rejects; heavily precipitated

Dust - Zip-locs not sealed; 68 screened

NOGALES, MEXICO

General - Samples received 12/5/75

Blood - Frozen; 15 badly clotted therefore duplicate FEP's run; condition required special mixing for Cd

Hair - Zip-locs mostly sealed; 47 rejects

Urine - Frozen; 7 rejects; precipitated

Dust - Zip-locs mostly sealed; 69 screened

B. Special Research Studies - The deviations of the actual samples received from the Government specification as set forth in the RFP were of such magnitude that it was necessary to conduct two special research studies before a final analysis scheme could be established.

1. Urine Precipitate Problems--Essentially, all urine samples contained a precipitate. Since a number of arsenic compounds are extremely volatile, heating the sample to dissolve the precipitate was not a feasible approach. The best solution to the problem would have been to prepare the entire sample, as received, for analysis. However, this solution to the problem was not economically feasible. The extreme variability in sample size would have required custom adjustments of the amount of digestion acid required for dissolution, as well as the final sample volume. These adjustments would, therefore, create preparation procedures unique for each individual urine sample. Additionally, data retrieval, key-punching, and verification involvement would have increased by more than a factor of three.

The only practical approach to the problem was to try to remove a representative aliquot from each sample. One of the larger urine samples from a lead smelter area was shaken vigorously and divided into four aliquots of 25 ml each and one final sample of 19 ml. All were analyzed for arsenic.

Results: As = 34 ppb $\pm$ 6 ppb (or 3.4 $\pm$ 0.6 µg/100 ml)
(95% Confidence Interval)

Coefficient of Variation = 8.82%

Based on these data, this aliquoting approach was adopted as a compromise preparation procedure. Actual experience with the samples in the contract revealed that some samples produced a relatively homogeneous sample after vigorous shaking while others still contained rather large precipitated aggregates.

2. Dust Collection Background Study--The RFP specifications called for dust samples of at least 100 mg. In actuality, the dust samples were collected by a technique[1] which does not allow for an actual measurement of the weight of the dust collected. A dust smear was collected from the top of a door facing using a moist, disposable paper towel, size 14 X 20 cm (44 in^2) impregnated with 20% denatured alcohol and 1:750 benzalkonium chloride. The towelette most frequently used was Wash 'n Dri from Canaan Products, Inc., Canaan, Conn. Because of the inconsistency in the manner by which the samples were taken and because of the varying mass of the dust collected, the only analysis avenue open was to employ the sample preparation procedure used by Vostal and associates in their study.

   Actual blank towelettes from the lots used to sample the smelters were not available for background determinations. Consequently, background data were obtained from one box of 26 towelettes

[1] Vostal, J. Tares, E. Sayre, J. W., and Charney, E., Environmental Health Prospectives, May, 1974, p 71.

supplied to the Contractor by CDC. The results obtained for the towelette background contribution are contained in Table 3. Appropriate background corrections were applied to all dust data. Data obtained by the above described method are representative of the 0.1 N HCL soluble content of the samples. No relationship can be established between this value and the total metal content of the dust.

C. Analytical Methodology and Discussion - A number of modifications in the analytical approach and methodology proposed by the Contractor for the fulfillment of this contract were required because of the size and condition of the samples actually received for analysis. This section discusses these modifications and the analytical methods actually employed.

1. FEP Analysis of Blood--The original RFP specified that blood samples would be maintained on ice in the dark from time of collection until an aliquot was taken for FEP determination at the contracting laboratory. Based on the assumption that the samples would be handled in the prescribed manner, the method chosen by the Contractor for the FEP determination was the method of Joselow which measures the fluorescence of zinc protoporphyrin. When the samples arrived, it was learned that many had been collected for three months or more and stored in a frozen state for varying periods of time. It was, therefore, necessary to change from the method of Joselow to the method of Sassa; and measure all erythrocyte porphyrins. The analytical

TABLE 3. Towelette Background Data

Concentrations are expressed as total micrograms per towelette

Sample No.	Lead	Cadmium	Arsenic	Copper	Zinc
R 3214	<0.25	<0.025	<0.025	1.75	3.25
R 3215	<0.25	<0.025	<0.025	1.25	3.00
R 3216	<0.25	<0.025	<0.025	1.63	4.50
R 3217	<0.25	<0.025	<0.025	1.81	1.00
R 3218	<0.25	<0.025	<0.025	1.88	4.25
R 3219	<0.25	<0.025	<0.025	1.40	4.13
R 3220	<0.25	<0.025	<0.025	1.50	11.8
R 3221	<0.25	<0.025	<0.025	1.38	3.50
R 3222	<0.25	<0.025	<0.025	1.63	4.75
R 3223	<0.25	<0.025	<0.025	1.88	3.25
Mean Value	<0.25	<0.025	<0.025	1.61	4.34

method of Sassa is the referee method employed by CDC for FEP determinations.[2]

2. Analysis of Blood for Heavy Metals--The original sample preparation proposed by the Contractor called for the samples to be lyophilized and for the organic matrix to be destroyed by oxygen-flask combustion. Prior to this step, however, a microsample (50 µl) was to be removed for lead analysis by direct flameless atomic absorption spectroscopy. The presence of many macroclotted blood samples made it impossible to withdraw valid microsamples for the blood lead analyses. To overcome this problem, the proposed sample preparation scheme for blood was replaced with a wet, acid-oxidation preparation of the total sample (NIOSH Methods P & CAM 101 and 139).

The acid digest solution was then analyzed by conventional atomic absorption for copper and zinc and the lead was determined by direct flameless atomic absorption (using a graphite furnace with multi-linear temperature programming and simultaneous background correction).

At this time, a request was received from the Project Officer to add an analysis for cadmium on selected blood samples. Preliminary investigation revealed that the blank correction for the acid-digestion sample preparation was too high for cadmium to give reliable analytical data. The following analytical procedure was found to give acceptable results in all cases except for those with excessive macroclots. Blood samples, in

[2]Granick, S., Sassa, S., Granick, J. L., Levere, R. D., and Kappas, A. (1972) Proc. Nat. Acad. Sci. USA. 69, 9, 2381-2385.

their original collection containers, were placed on a vortex mixer for two minutes. A 250 µl sample was withdrawn with an Eppendorf pipette and diluted to five ml with distilled water. An equal aliquot of sample and 1% ammonium sulfate solution (Cd free) were placed in a pyrolytic graphite tube and analyzed by flameless atomic absorption.

3. Analysis of Hair for Heavy Metals--All hair samples were washed with agitation for 30 minutes in a non-ionic detergent (7-X-O-Matic) and thoroughly rinsed with distilled deionized water. Samples were then dried (vacuum oven 60° C, 0.5 atm.) and weighed. The original proposal called for the organic matrix to be destroyed by oxygen-flask combustion. This, however, was replaced with the acid-oxidation preparation technique being used for blood and urine since the results obtained by both techniques are comparable. Conventional atomic absorption was employed for the analysis of cadmium and lead in hair while the gaseous hydride atomic absorption method was used for arsenic.

4. Analysis of Urine for Arsenic--The method originally proposed and actually used for the analysis of arsenic in urine is the NIOSH Method No. P & CAM 139. The samples are ashed with a mixture of nitric, perchloric, and sulfuric acids to destroy the organic matrix. The ash is treated with ammonium oxalate to remove traces of nitric acid and the solution is analyzed by atomic absorption of the gaseous hydride (arsine).

5. Analysis of House Dust--The Contractor originally proposed to

follow the sample preparation procedure for house dust given in the RFP as the recommended method. Specifically, the "as received" sample was to be weighed and then sieved through a 0.5 mm screen while being shaken for five minutes at 260 oscillations per minute. The sieved portion was then to be weighed and extracted with quartz distilled nitric acid (6N) at 50° C for 30 minutes. The extract was then to be filtered and analyzed for Pb, Cd, Zn, and Cu by atomic absorption.

An aliquot of the filtered HNO_3 acid extract was to be treated to remove all traces of nitric acid and then analyzed for arsenic by the gaseous hydride-atomic absorption technique.

Additionally, on a selected number of house dust samples, an extract was to be made on a portion of the unsieved sample and a comparative analysis was to be made on both sieved and unsieved portions.

As stated in the previous section of this report, the dust samples were collected on moist, commercial towelettes. The sample preparation method prescribed for use in the RFP is applicable only to dust free from the collection matrix. Consequently, the entire sample, towelette plus dust, was soaked at room temperature for 16 hours in 20 ml of 0.1 N HCL. The eluates were decanted, final volume was adjusted to 25 ml, and analyses were performed for the elements of interest--conventional atomic absorption for Pb, Cd, Zn, Cu, and atomic absorption of a gaseous hydride for As.

In summary, the employed analytical methodology represents

current, state-or-the-art approaches which are basically sound from a technical standpoint. Documentation of the accuracy and precision of the methods are contained in the section of this report which deals with the internal analytical quality control program. The limits of detection for the various elements in the appropriate analysis solutions are contained in Table 4.

D. Review of Quality Control Program - This contract required two quality control programs--a documented internal analytical quality control program, not to exceed 10% of the total effort, and an external control program, not to exceed 1%. All quality control efforts were in addition to the contract samples.

The internal quality control program encompassed blind split sample analyses for hair, blood, and urine; blind random analyses of standard reference samples; recovery and precision studies from two large, composite samples (blood and hair); and the analysis of standard sample splits with two reference laboratories.

The external control program was to consist of blind split sample analyses, blind known samples to be analyzed concurrently with contract batches of samples, and duplicate determinations to be performed by reference laboratories.

Each 50th blood and urine sample was split into two parts by the Contractor and one of the aliquots of each was analyzed by the the Contractor. The other portion was delivered to the EPA Project Officer for analysis in EPA's laboratory. The Contractor was not required to split hair samples for duplicate analysis as a part of the Scope of Work of the contract.

TABLE 4. Limits of Detection

Concentration units are micrograms per liter (parts per billion)

Element	Detection Limit, ppb
Arsenic	1.
Copper	10.
Zinc	10.
Lead	
Conventional A.A.	10.
Flameless A.A.	0.5
Cadmium	
Conventional A.A.	1.
Flameless A.A.	0.02

This section of the final report deals with the internal analytical quality control program. Because of the importance of laboratory analyses and the resulting actions which they produce, a program to insure the reliability of the data is essential. Data from a valid analytical quality control program provide an assessment and measurement of the precision and accuracy of the analytical results. In addition, a properly designed and conducted program will identify any segment of the total effort which is "out of control."

1. Accuracy--Accuracy refers to the degree of difference between observed and known, or actual values. Two approaches were used to establish the accuracy of the analytical data--recovery studies and the analysis of standard reference materials.

   a. Recovery Studies--These studies were conducted on an actual sample and not on reference standards. At the outset of this project, a pint of blood was secured from the local blood bank. The entire sample was lyophilized and homogenized to form a large, stable blood composite for use in the internal quality control program. Known amounts of copper, zinc, and lead were added to an aliquot of the control blood sample. Using the composite lyophilized blood sample, with known concentrations of 17.5 µg/g zinc, 4.60 µg/g copper, and 0.79 µg/g lead, recoveries were 98%, 99%, and 97% respectively. Individual results of this study are found in Table 5.

   b. Standard Reference Materials (SRM) Analysis--Two standard samples were used to provide a measure of the control of accuracy

TABLE 5. Recovery Study Data

Concentration units are micrograms per gram lyophilized whole blood

Copper

Sample No.	Sample Concentration	Added Spike	Sample Plus Spike	Percent Recovery
R 3007	4.60	3.0	7.78	102.
R 3008	4.60	3.0	7.35	97.
R 3009	4.60	3.0	7.65	101.
R 3010	4.60	3.0	7.45	98.
R 3011	4.60	3.0	7.36	97.
			Average Recovery	99.%

Zinc

Sample No.	Sample Concentration	Added Spike	Sample Plus Spike	Percent Recovery
R 3012	17.5	10.0	26.1	95.
R 3013	17.5	10.0	27.0	97.
R 3014	17.5	10.0	28.3	103.
R 3015	17.5	10.0	25.4	92.
R 3016	17.5	10.0	28.0	103.
			Average Recovery	98.%

Lead

Sample No.	Sample Concentration	Added Spike	Sample Plus Spike	Percent Recovery
R 3017	0.79	1.0	1.68	94.
R 3018	0.79	1.0	1.88	105.
R 3019	0.79	1.0	1.70	95.
R 3020	0.79	1.0	1.64	92.
R 3021	0.79	1.0	1.73	97.
			Average Recovery	97.%

during the analysis stage of the contract. These two samples were Lyophilized Bovine Liver (SRM 1577) from the National Bureau of Standards and Dried Animal Whole Blood (Code No. A-2/1974) from the International Atomic Energy Commission.

Prior to the analysis of any samples from the contract, eight aliquots from each of these reference materials were prepared for analysis in order to verify the proposed analytical methodology.

The bovine liver sample was analyzed first. Results of these tests are contained in Table 6 . These data show no significant difference between the actual analysis mean and the certified value for cadmium, lead, and zinc. However, a relative error of +3.59% was observed in the case of copper. Subsequent investigation traced the bias to the master copper standard employed for the atomic absorption analysis. This problem was corrected, and the animal blood standard samples were analyzed. Results for these samples are found in Table 7. All of the elements analyzed, including copper, showed no significant difference between the actual analysis mean and the recommended values for the standard.

In order to provide a measure of accuracy from analysis batch to batch, a blind sample of one of these standard reference samples was analyzed with the samples from each

TABLE 6. Analysis of Standard Reference Material 1577 Bovine Liver

Source: National Bureau of Standards

Concentrations are expressed as micrograms per gram (ppm)

Sample No.	Copper	Zinc	Lead	Cadmium
R 3030	199.	137.	0.33	0.27
R 3031	209.	135.	0.25	0.31
R 3032	201.	131.	0.31	0.28
R 3033	204.	128.	0.35	0.25
R 3034	192.	128.	0.35	0.26
R 3035	188.	133.	0.36	0.29
R 3036	186.	130.	0.36	0.27
R 3037	197.	138.	0.36	0.26
Mean Value (95% Confidence Interval)	197. ± 6.6	133. ± 3.3	0.33 ± 0.03	0.27 ± 0.02
Coefficient of Variation	4.02%	2.93%	11.4%	7.02%
Standard Values (95% Confidence Interval)	193. ± 10	130. ± 10	0.34 ± 0.08	0.27 ± 0.04

TABLE 7. Analysis of Dried Animal Whole Blood, Reference Material (Code No. A-2/1974)

Source: International Atomic Energy Commission

Concentrations are expressed as micrograms per gram (ppm)

Sample No.	Copper	Zinc	Lead
R 3022	50.5	88.6	0.86
R 3023	51.6	90.2	0.89
R 3024	44.3	89.4	0.99
R 3025	45.0	86.7	0.90
R 3026	51.5	88.4	0.96
R 3027	47.2	90.3	0.90
R 3028	44.1	91.2	0.97
R 3029	43.9	88.7	0.96
Mean Value (95% Confidence Interval)	47.3 ± 2.9	89.2 ± 1.2	0.93 ± 0.04
Coefficient of Variation	7.26%	1.57%	5.03%
Standard Values (95% Confidence Interval)	45. ± 6	89. ± 9	0.97 ± 0.22

smelter and/or control site. These data are tabulated in Tables 8 and 9. An examination of these data shows no significant deviation from the standard value of the reference samples.

Based on both the recovery studies and the actual analysis of these standard reference materials, it can be stated that at the 95% confidence interval the overall accuracy of the analytical data is 98% or better.

2. Precision--Precision is a measure of mutual agreement among individual measurements of the same property under prescribed similar conditions. In an analytical quality control program, precision is determined, not on reference standards, but by the use of actual samples which incorporate the inherent matrix variables associated with the sample type under investigation.

   a. Quality Control Charts--Analytical quality control charts visibly represent the continuing validity of routine analytical data and the performance of individual analysts within a given laboratory. Limits for these control charts are calculated using the repeatability standard deviation for the control sample. Upper and lower control limits (UCL and LCL) are defined as $\pm$ 3 standard deviations while upper and lower warning limits (UWL and LWL) are set at $\pm$ 2 standard deviations. For any given period, if all points on the control chart are within the control limits and somewhat randomly distributed about the mean value, it can be

TABLE 8. Analysis of IAIA Animal Blood (Code No. A-2/1974)

Sample No.	Batch No.	Copper	Zinc	Lead
GF 6129	2	50.5	89.0	0.86
GF 6131	2	46.1	94.5	0.96
GF 5079	3	44.4	86.3	0.89
GF 5080	3	42.8	85.2	0.90
GF 5861	4	47.9	88.6	0.99
GF 6040	4	51.2	89.0	0.97
GF 6240	5	48.7	91.8	0.90
GF 6385	5	42.3	93.4	0.96
GF 7164	6	44.6	82.9	0.93
GF 7363	6	43.0	85.6	0.99
Mean Value (95% Confidence Interval)		46.2 ± 2.3	88.6 ± 2.7	0.94 ± 0.03
Coefficient of Variation		7.06%	4.23%	4.87%
Standard Values (95% Confidence Interval)		45. ± 6	89. ± 9	0.97 ± 0.22

TABLE 9. Analysis of NBS Bovine Liver (SRM 1577)

Sample No.	Batch No.	Copper	Zinc	Lead
GF 5582	2	201.	135.	0.33
GF 5583	2	194.	128.	0.35
GF 5824	3	190.	133.	0.25
GF 5893	3	194.	130.	0.36
GF 5811	4	189.	136.	0.31
GF 5938	4	193.	128.	0.36
GF 6217	5	195.	128.	0.35
GF 6359	5	201.	130.	0.36
GF 7072	6	203.	126.	0.30
GF 7310	6	189.	134.	0.39
GF 7473	6	194.	131.	0.40
Mean Value (95% Confidence Interval)		195. ± 3.3	131. ± 2.2	0.34 ± 0.03
Coefficient of Variation		2.51%	2.51%	12.5%
Certified Values (95% Confidence Interval)		193. ± 10	130. ± 10	0.34 ± 0.08

assumed that the precision of the analyses is consistent with the precision of the internal quality control sample.

The quality control sample used to generate the quality control charts relating to blood analyses was an aliquot of the lyophilized blood composite used for the recovery study. A fresh urine composite sample was used for the arsenic control. Representative quality control charts generated through the use of these samples are illustrated by Figures 1-10. Typical variability in precision among analysts is demonstrated by a comparison of Figures 1-3 and 4-6. These charts profile the precision of the analytical methodology employed for the analysis of lead, zinc, and copper in blood and arsenic in urine. Comparable charts were also developed for the analysis of arsenic, lead, and cadmium in hair and cadmium in blood.

A summary of the statistical profile generated by the control chart data is contained in Table 10. The following measures apply:

Standard Deviation (s). The square root of the variance.

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

where $\bar{x}$ is the mean of the samples.

Coefficient of Variation (V) or Percent Relative Standard Deviation (% RSD).

$$V = \frac{100\ s}{\bar{x}},$$

where $\bar{x}$ is the mean and s the standard deviation of the sample.

95% Confidence Interval. The interval expressed by $\bar{x} \pm t(\nu, F=.975)s/\sqrt{n}$, where $\nu = n-1$ and where t is taken from tables of the t-distribution, is sufficiently wide to grant that the mean of the whole population has a 95% chance of falling in the interval. Such tables may be found in most of the CRC mathematics publications.

The average coefficient of variation for the four elements is 3.91%. The range exhibited by V is 1.15% to 5.98%.

b. Composite Hair Analysis--Two composite hair samples were a part of the internal quality control program. In order to establish the inherent variability of a given hair sample, a special study was designed using one of these composites. The entire sample (~ 10 grams) was washed and dried according to routine standard procedures. The sample was then cut into one-quarter inch lengths and mixed thoroughly. Ten aliquots of the dried hair, weighing 0.5 gm each, were removed and analyzed individually. The remainder of the hair was initially processed as one sample; then, after dissolution, ten aliquots were removed from the prepared sample solution and analyzed.

FIGURE 1. CONTROL CHART FOR ZINC IN BLOOD ANALYST: 17
DATE: 12-11-75

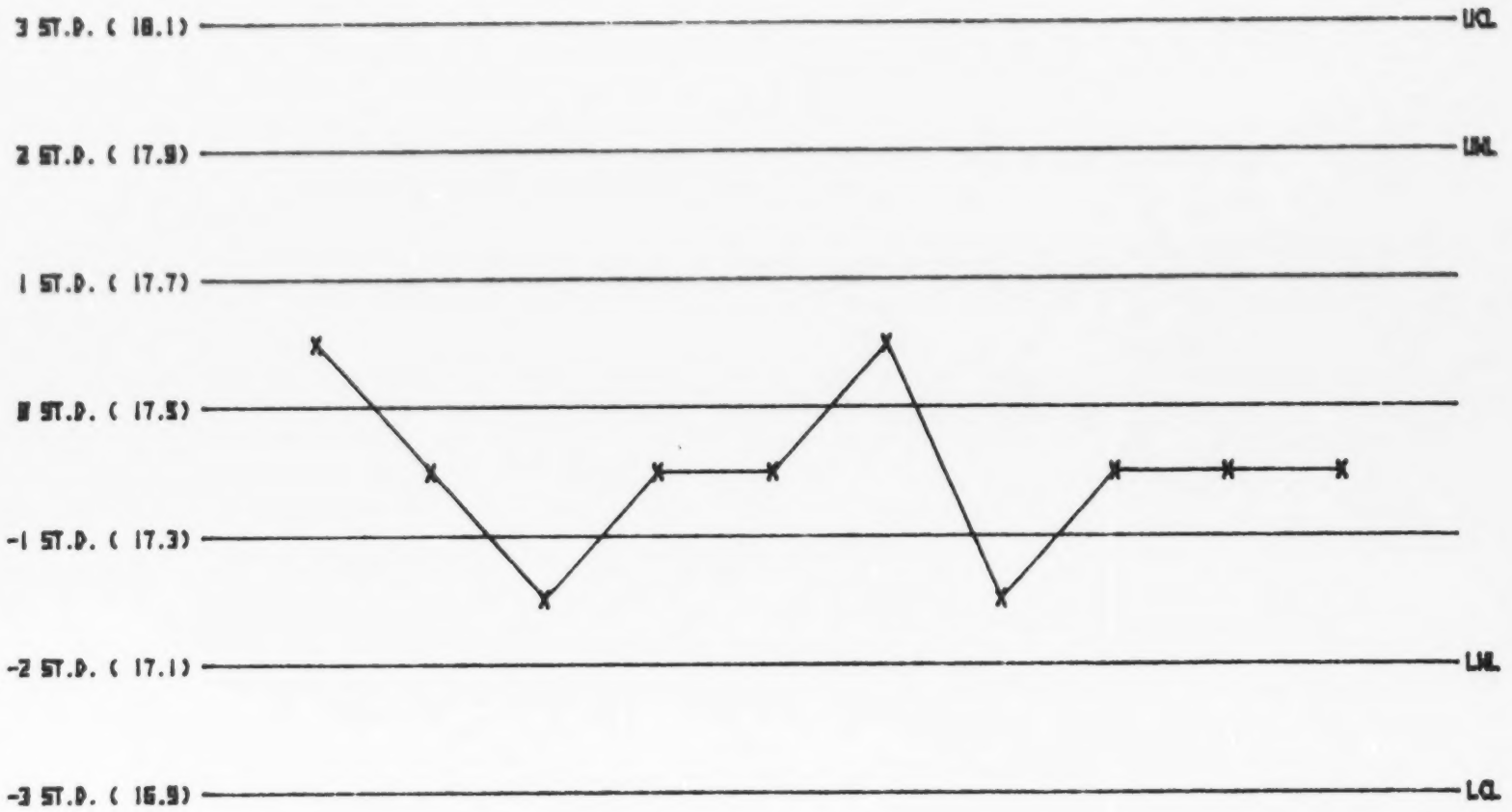

FIGURE 2. CONTROL CHART FOR ZINC IN BLOOD ANALYST: 1
DATE: 12-12-75

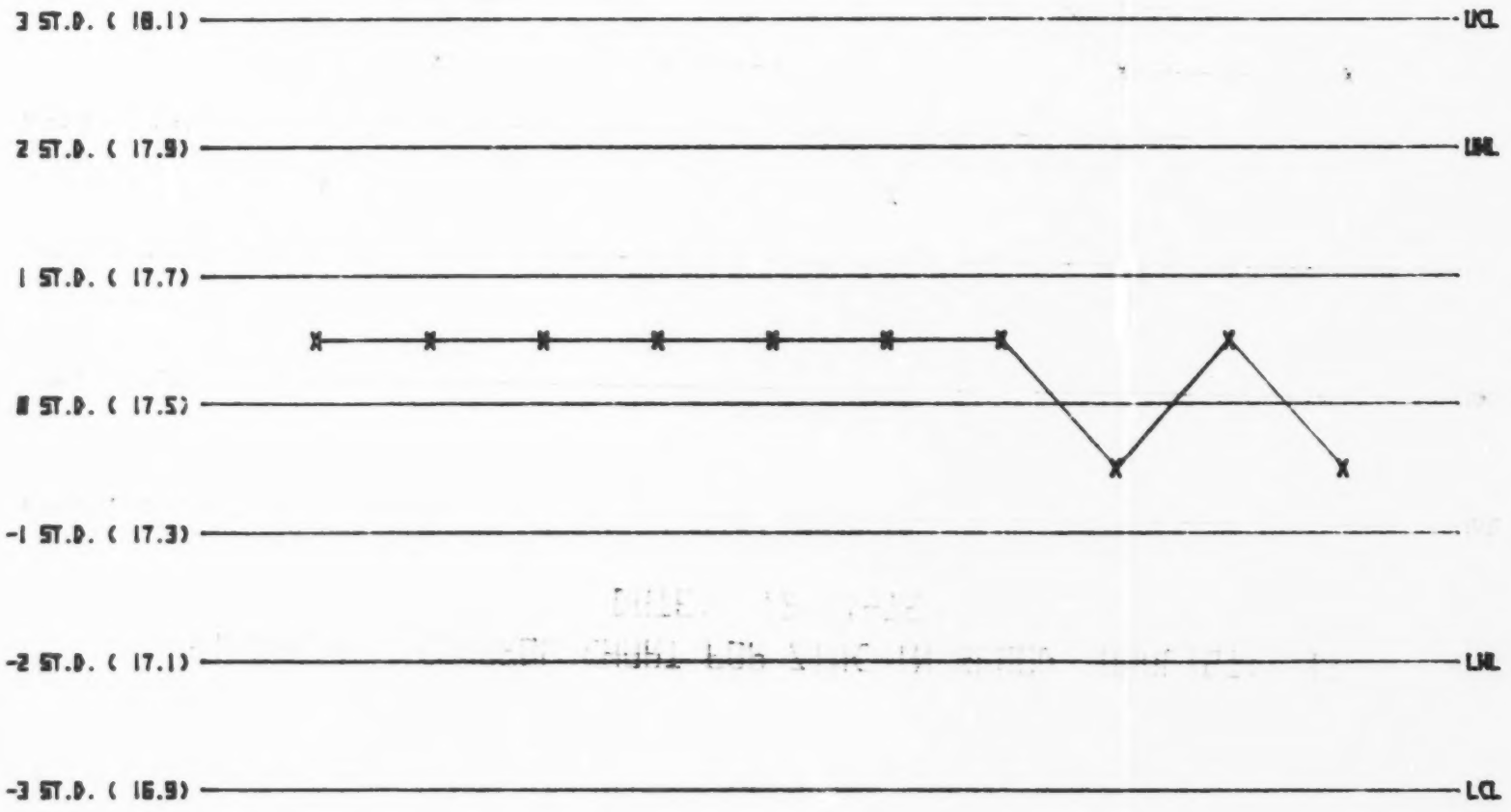

FIGURE 3. CONTROL CHART FOR ZINC IN BLOOD ANALYST: 13
DATE: 12-16-75

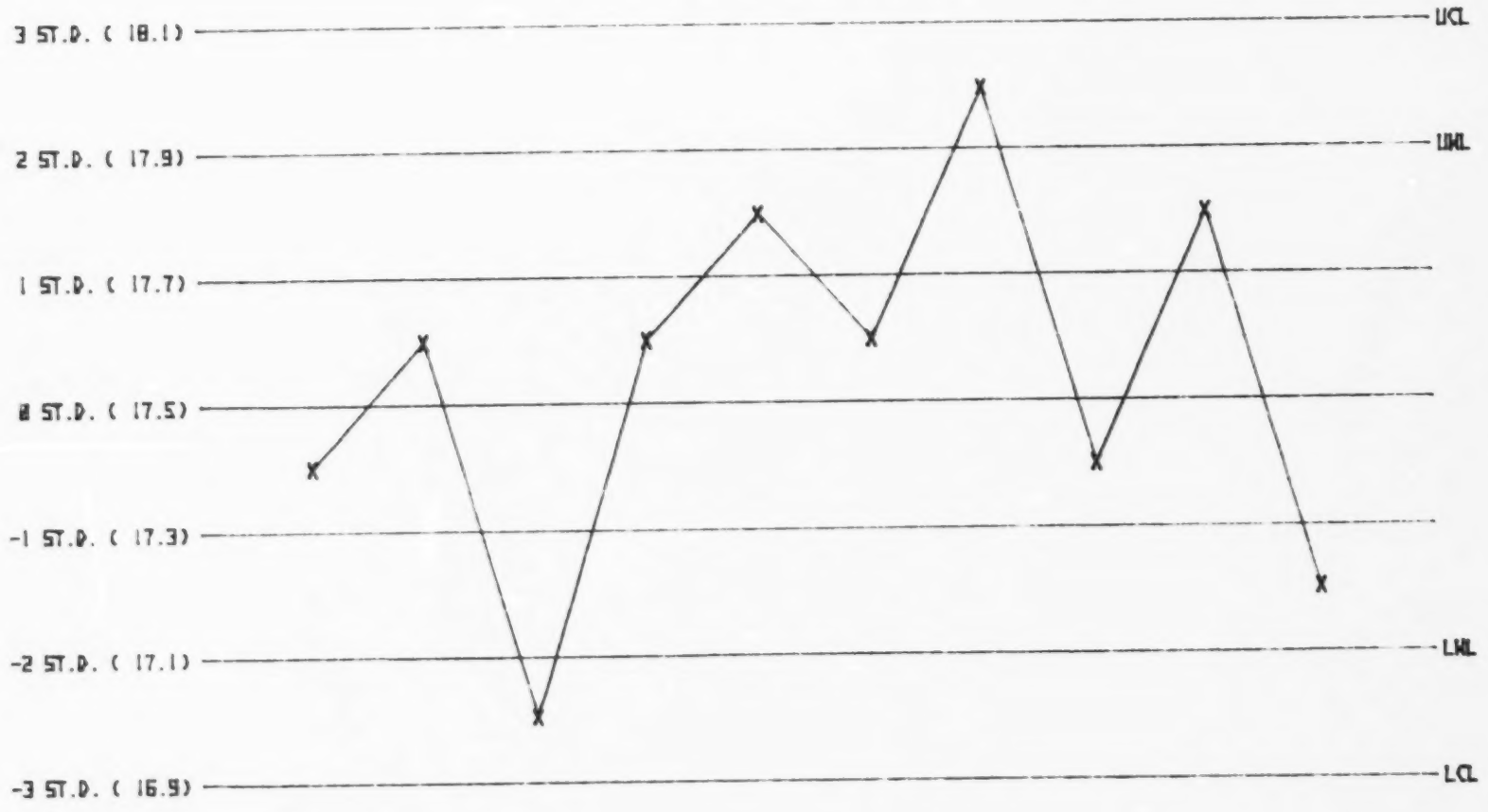

FIGURE 4. CONTROL CHART FOR COPPER IN BLOOD ANALYST: 17
DATE: 12-11-75

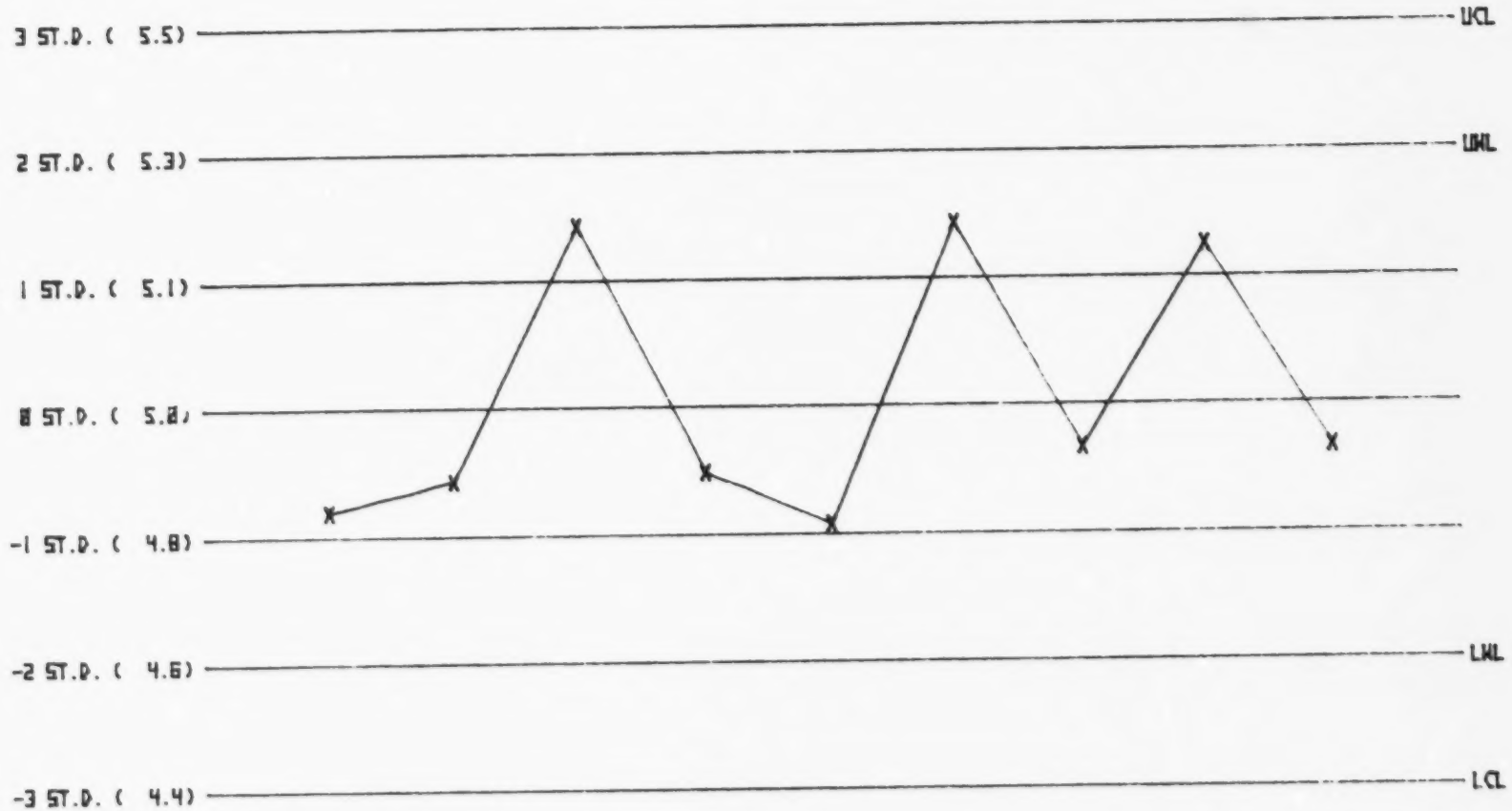

FIGURE 5. CONTROL CHART FOR COPPER IN BLOOD ANALYST: 1
DATE: 12-12-75

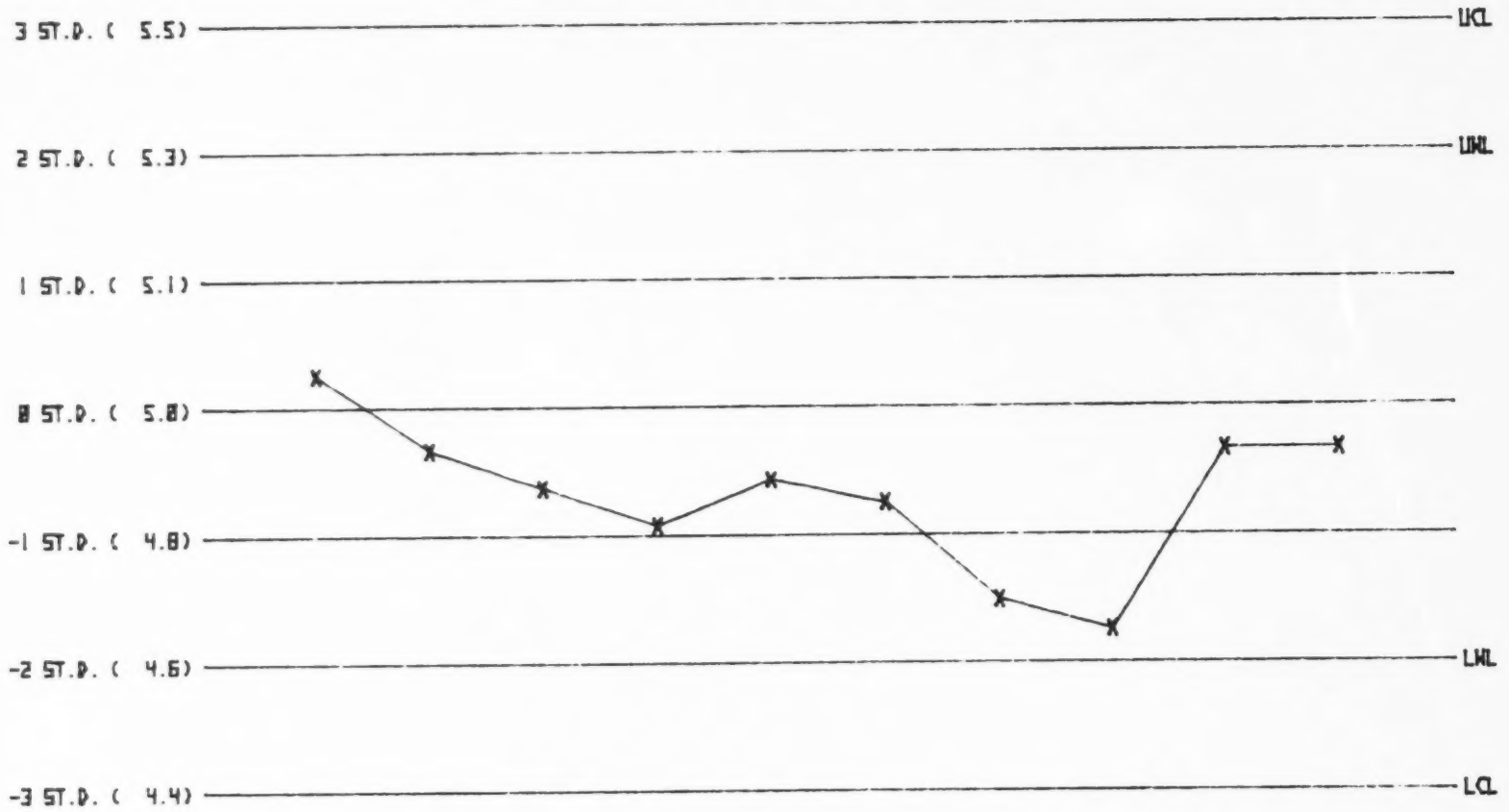

FIGURE 6. CONTROL CHART FOR COPPER IN BLOOD ANALYST: 13
DATE: 12-16-75

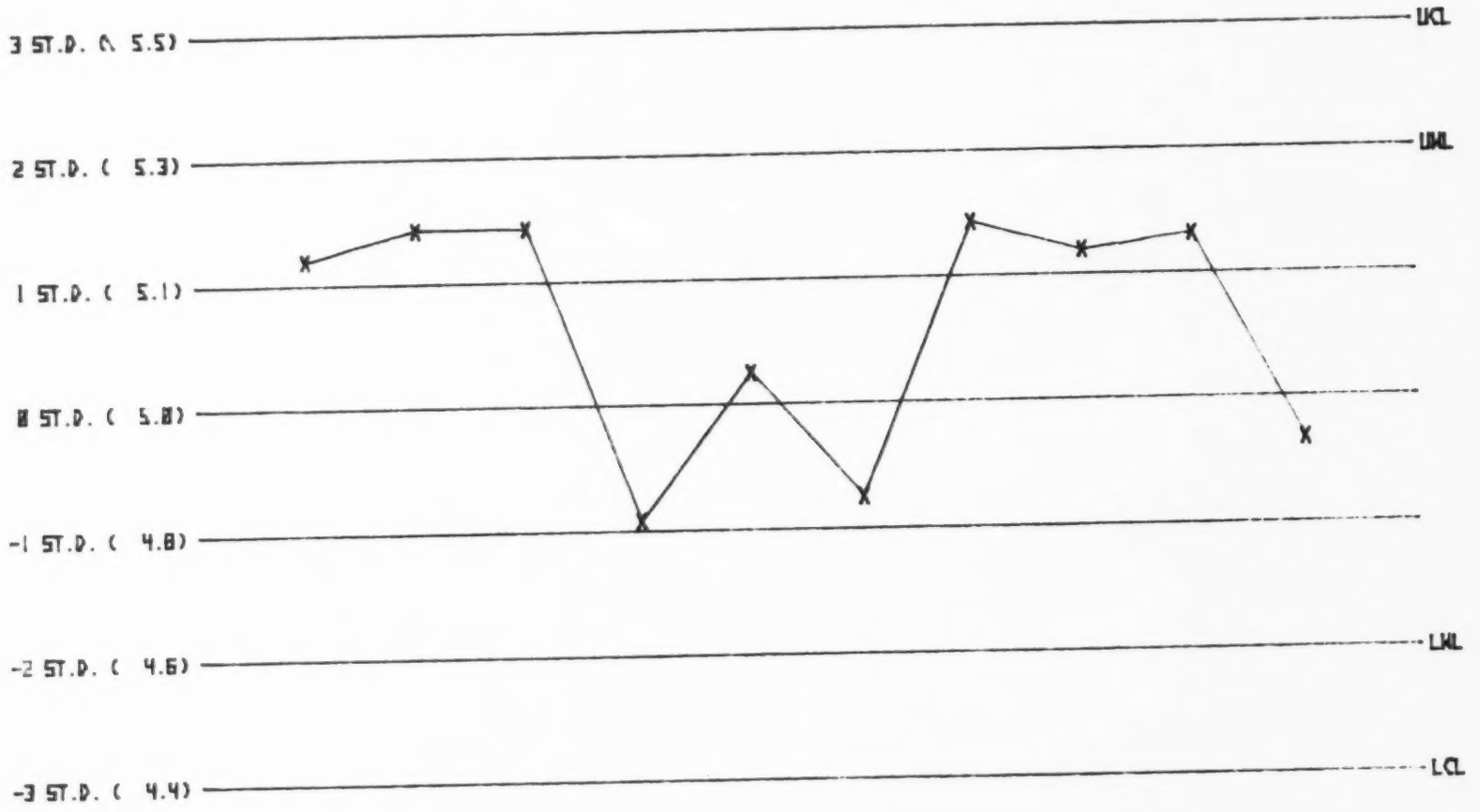

FIGURE 7. CONTROL CHART FOR ARSENIC IN URINE ANALYST: 17
DATE: 11-19-75

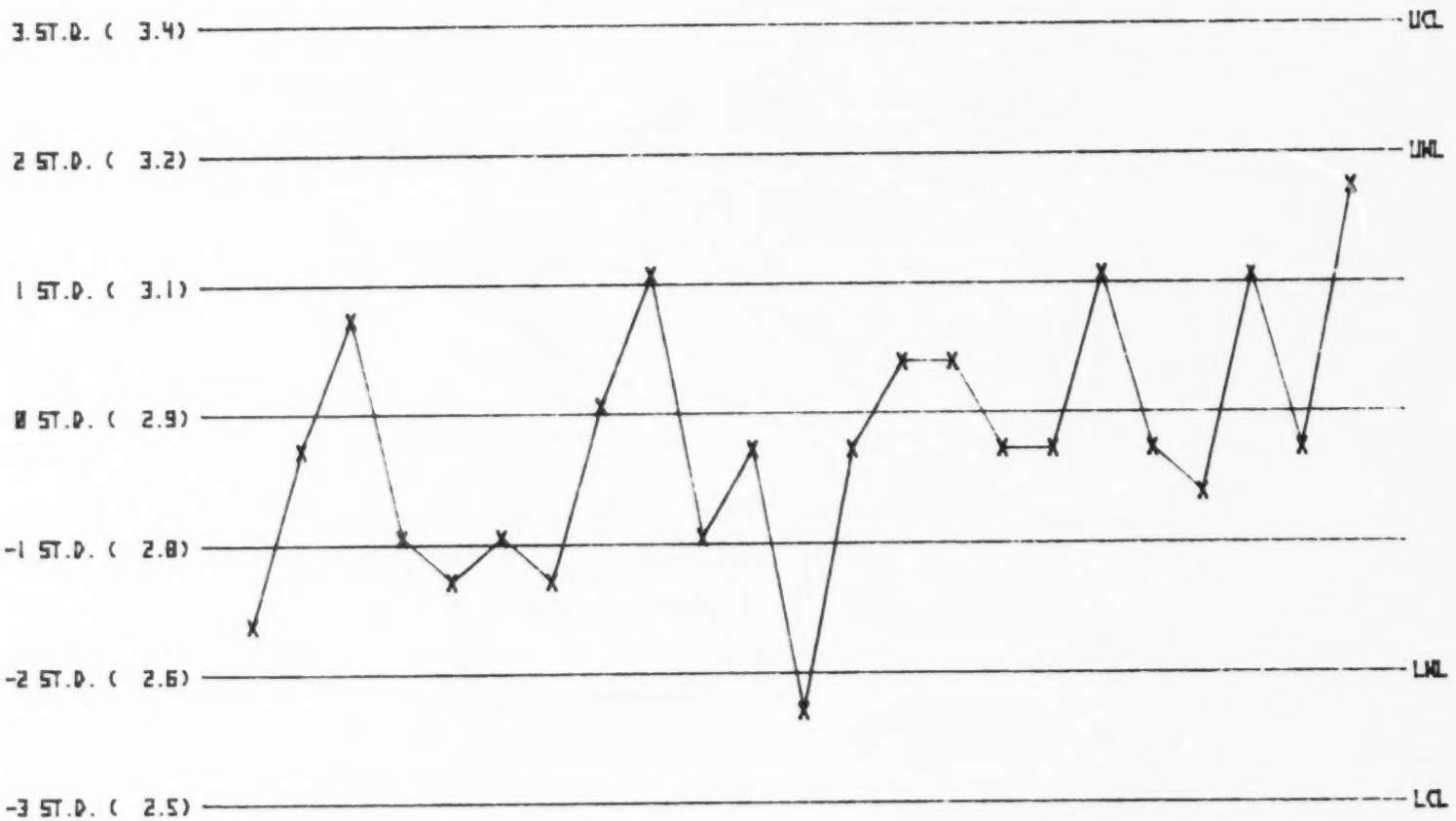

FIGURE 8. CONTROL CHART FOR ARSENIC IN URINE ANALYST: 17
DATE: 11-20-75

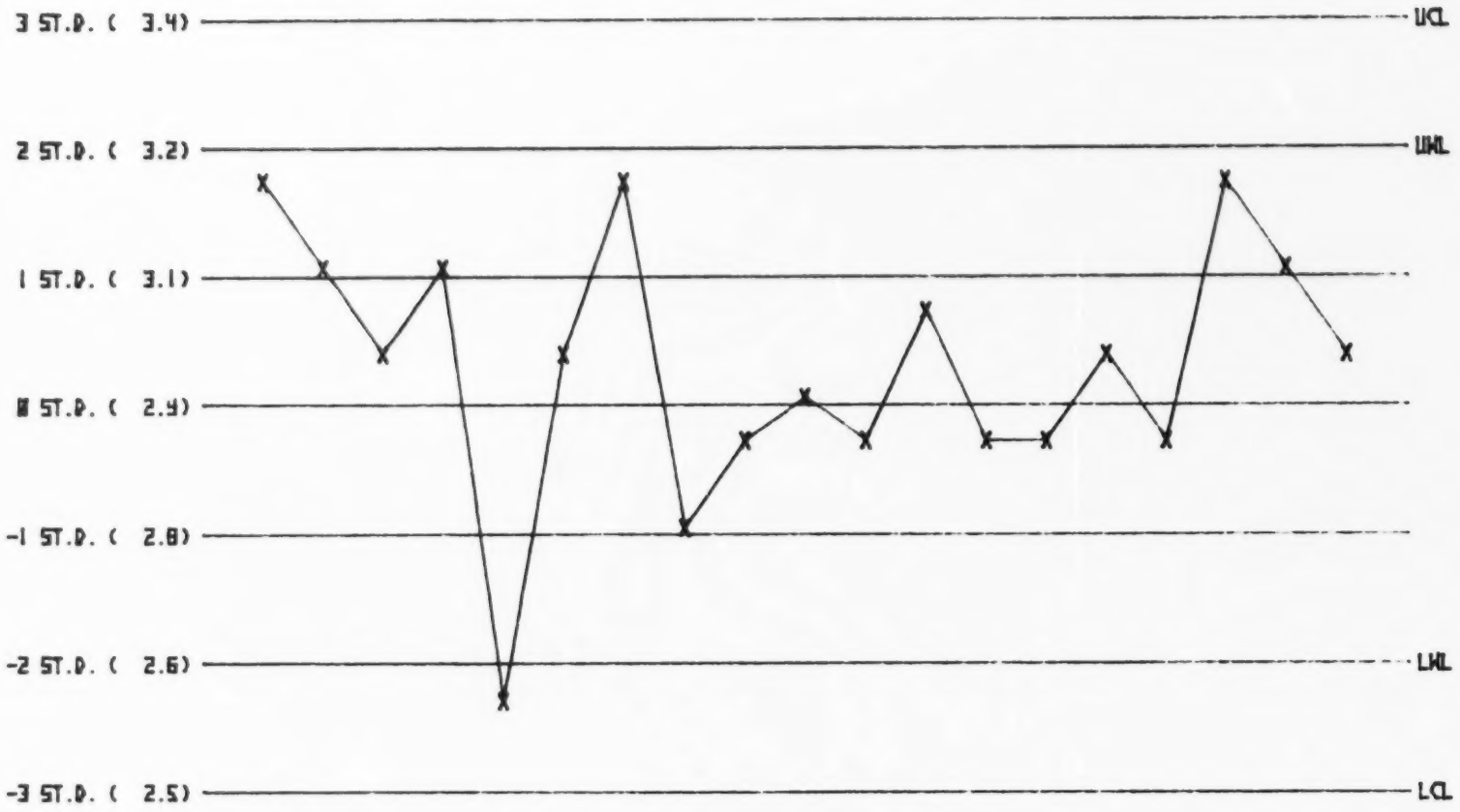

FIGURE 9. CONTROL CHART FOR ARSENIC IN URINE ANALYST: 1
DATE: 12-2-75

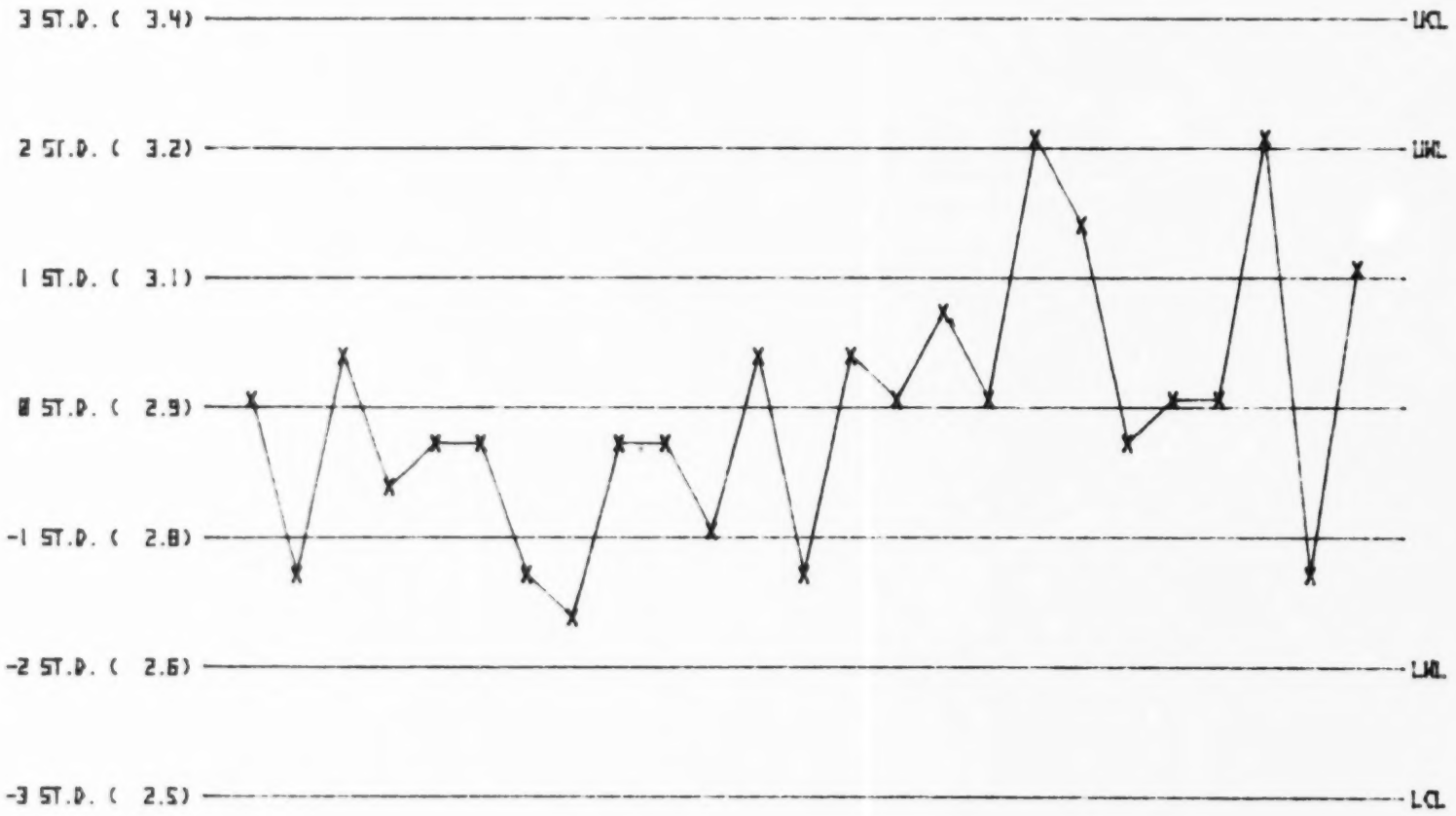

FIGURE 10. CONTROL CHART FOR LEAD IN BLOOD ANALYST: 2 AND 22
DATE: 12-28-75

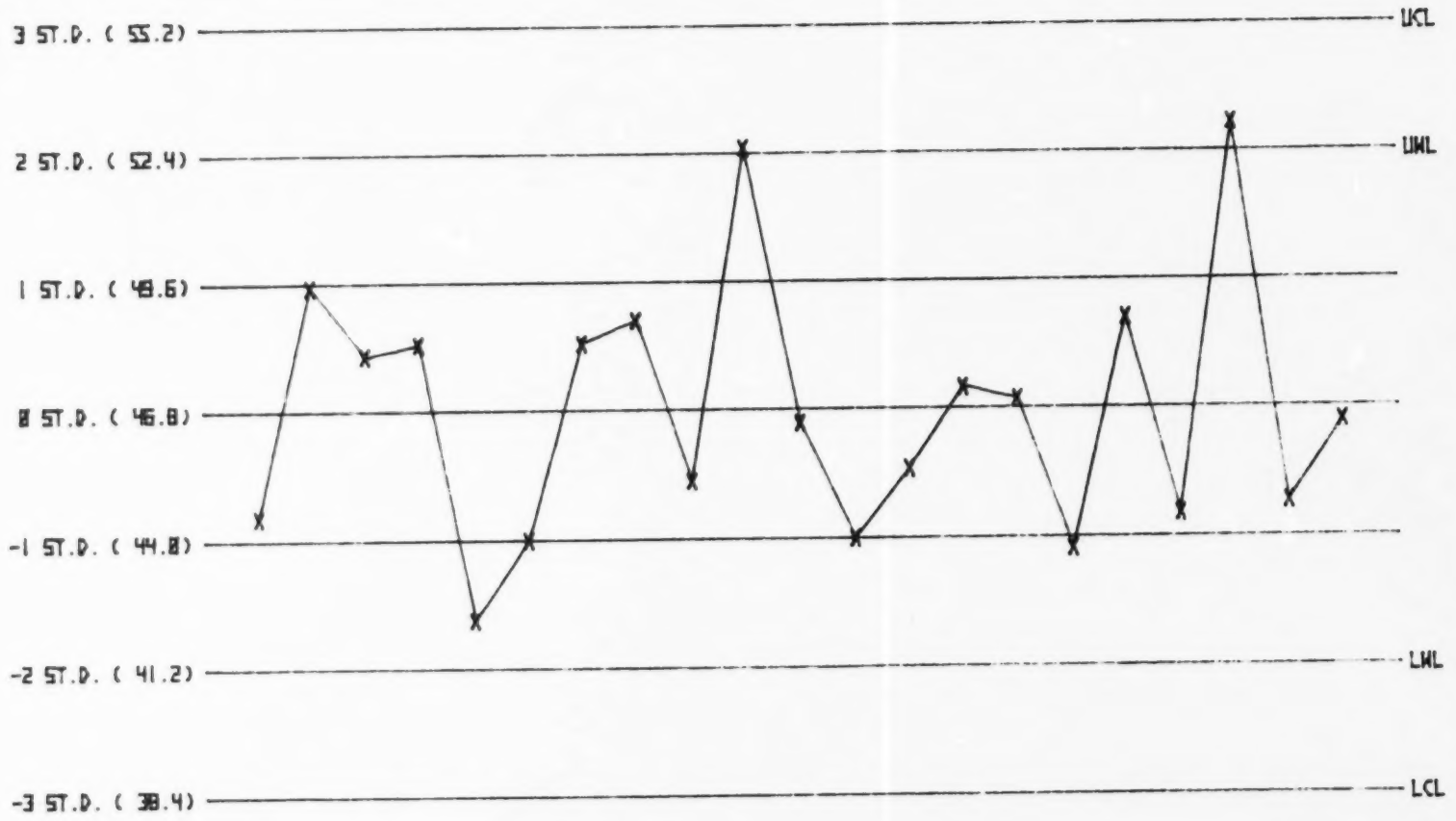

TABLE 10. Summary of Control Chart Data

		Copper (ppm)	Zinc (ppm)	Lead (ppb)	Arsenic (ppm)
Mean		4.96	17.5	46.8	2.94
Standard Deviation abs.		0.17	0.20	2.80	0.15
Uncertainty Limits of Mean (95% Confidence Interval)	abs. ±	0.07	± 0.08	± 1.3	± 0.04
	rel %±	1.31	± 0.43	± 2.69	± 1.24
Coefficient of Variation		3.44%	1.15%	5.98%	5.06%

A comparison of the precision measurements between the 4.49 gm dissolved composite (Table 11) and the ten individual 0.5 gm dry hair aliquots (Table 12) clearly differentiates the reproducibility of the analytical instrumentation, as defined by the former, from the inherent elemental variability in hair, as shown by the latter. These data conclusively demonstrate the significance and magnitude of this variation in trace metal concentrations when small individual hair samples are compared analytically. A comparative summary of these statistical profiles is found in Table 13.

Another study was conducted on a second hair composite. The composite was divided into thirteen individual 0.5 gm samples. These samples were submitted to the laboratory as blind samples in the last three batches of the project. The analytical results are given in Table 14.

Based on these three studies, the innate variability of certain elements in hair was clearly demonstrated. This fact will have a significant bearing on the accurate interpretation of the blind sample split analyses conducted for this contract. This topic will be discussed in detail in a later section of this report.

3. Interlaboratory Comparison Analyses

a. Comparative Arsenic Analyses--Concurrent with this contract effort, the Contractor was employed by EPA to analyze

TABLE 11. Analytical Data from 10 Aliquots of Composite Hair Sample (4.49 grams) - Prepared as One Single Sample.

Concentration units are micrograms per gram

Sample No.	Lead	Cadmium	Arsenic	Copper	Zinc
BB 007-1	10.0	1.45	<0.05	24.3	497.
BB 007-2	10.0	1.50	<0.05	24.6	497.
BB 007-3	10.0	1.45	<0.05	24.4	497.
BB 007-4	9.85	1.45	<0.05	24.6	497.
BB 007-5	9.80	1.45	<0.05	24.3	497.
BB 007-6	9.90	1.45	<0.05	24.3	497.
BB 007-7	10.0	1.45	<0.05	24.3	500.
BB 007-8	10.1	1.45	<0.05	24.3	494.
BB 007-9	10.0	1.50	<0.05	24.6	494.
BB 007-10	10.0	1.45	<0.05	24.3	494.
Mean Value abs. (95% Confidence Interval)	9.97 ± 0.06	1.46 ± 0.02	<0.05	24.4 ± 0.10	496. ± 1.
Standard Deviation, abs.	0.09	0.02		0.14	1.90
Coefficient of Variation	0.90%	1.44%	0	0.58%	0.38%

TABLE 12. Analytical Data for Ten Individual 0.5 gram Aliquots of Composite Hair Sample

Concentration units are micrograms per gram

Sample No.	Lead	Cadmium	Arsenic	Copper	Zinc
Z 019	8.80	0.67	<0.05	24.9	506.
Z 020	10.0	0.67	<0.05	30.1	593.
Z 021	11.3	1.11	0.10	27.1	521.
Z 022	12.5	1.22	<0.05	27.1	516.
Z 023	10.0	0.67	<0.05	24.6	481.
Z 024	10.0	0.75	0.10	25.9	491.
Z 025	10.0	1.50	0.06	27.1	526.
Z 026	17.5	2.13	<0.05	28.6	518.
Z 027	11.3	1.38	<0.05	25.1	488.
Z 028	10.0	0.88	<0.05	29.1	538.
Mean Value abs. (95% Confidence Interval)	11.1 ± 1.76	1.10 ± 0.34	≤0.06	27.0 ± 1.34	518. ± 22
Standard Deviation, abs.	2.46	0.48		1.87	32.
Coefficient of Variation	22.1%	43.4%		6.95%	6.19%

TABLE 13. Summary-Hair Study Precision Data

	Lead	Cadmium	Copper	Zinc
Mean Value, 95% Confidence Interval,				
Composite	9.97 ± 0.06	1.46 ± 0.02	24.4 ± 0.10	496 ± 1.35
Individual	11.1 ± 1.76	1.10 ± 0.34	27.0 ± 1.34	518 ± 22.9
Standard Deviation				
Composite	0.09	0.02	0.14	1.90
Individual	2.46	0.48	1.87	32.
Coefficient of Variation				
Composite	0.90%	1.44%	0.58%	0.38%
Individual	22.1%	43.4%	6.95%	6.19%

TABLE 14. Analysis of Quality Control Hair Composite No. 2

Concentration units are micrograms per gram

ample No.	Batch No.	Lead	Cadmium	Arsenic
F 5264	4	5.00	<0.25	0.25
F 5377	4	12.5	0.38	0.075
F 5487	4	11.3	0.25	0.35
F 5578	4	13.8	0.25	N. A.*
F 6727	5	11.3	0.25	0.40
F 6774	5	12.5	0.38	0.33
F 6846	5	11.3	0.25	0.28
F 6920	5	15.0	0.25	N. A.*
F 8270	6	10.0	0.75	0.28
F 8347	6	12.5	0.38	0.28
F 8389	6	11.3	0.75	N. A.*
F 8482	6	10.0	0.25	N. A.*
F 8561	6	7.50	<0.25	0.25
lean Value abs. (95% Confidence Interval)		11.1 ± 1.57	0.36 ± 0.11	
Standard Deviation, abs.		2.6	0.18	0.09
oefficient of Variation		23.5%	51.3%	32.7%

*N. A. = Not Analyzed. Sample was controlling a zinc smelter

arsenic in particulate matter. The analytical methodology employed in this effort was NIOSH Method P & CAM 139 (arsenic in urine and air) which is the identical method used for Contract No. 68-02-2266. In the initial phase of the aforementioned project, a correlation study was conducted to compare the NIOSH arsenic method with EPA flameless atomic absorption technique. Results of these analyses on sample splits provided and analyzed by EPA are given in Table 15. The correlation coefficient for these data is 0.9943.

b. Comparative Blood Lead Analyses--On December 30, 1975, the Contractor received twelve reference blood samples from the Center for Disease Control (CDC). The Contractor analyzed these samples by the graphite furnace atomic absorption technique. In addition, the three samples with the highest lead values were also analyzed by conventional atomic absorption.

A comparison of the data obtained by the Contractor with the CDC standard values is shown in Table 16. Performance evaluation by CDC was based on the following criteria:

For values $\geq$ 40 µg/100 ml, $\pm$ 15%

For values $<$ 40 µg/100 ml, $\pm$ 6 µg

In only one case out of twelve, did the Contractor's data differ from the CDC value by more than $\pm$ 6 µg. Sample 5-27 differed by 6.2 µg.

c. Interlaboratory Study Conclusions--Based on the results of

TABLE 15. Comparison of Analytical Results of the NIOSH and EPA Arsenic Methods

Concentrations are micrograms Arsenic per milliliter

Sample No.	Contractor Results (NIOSH Method P & CAM 139)	EPA Results (Flameless AA)
4	2.00	1.7
7	20.0	19.2
12	15.4	19.5
13	1.56	1.6
14	5.60	4.8
15	6.10	6.5
20	44.0	44.8

TABLE 16. Comparative Data - Blood Lead

(Concentrations are expressed as μg Pb/100 ml whole blood)

Contractor Code	CDC Code	Contractor Result	CDC Value
GF 6958	5-29	76.6 ± 3.6	71.8 ± 4.6
GF 6958*	5-29 Direct Aspiration	76.4 ± 2.1	
GF 6959	5-18	12.1 ± 2.1	14.4 ± 1.9
GF 6960	5-36	25.5 ± 2.0	26.4 ± 2.8
GF 6961	5-15	13.4 ± 1.0	16.3 ± 2.2
GF 6962	5-12	22.7 ± 0.8	19.7 ± 1.7
GF 6963	5-27	38.0 ± 0.9	31.8 ± 1.1
GF 6964	5-24	37.2 ± 1.3	33.2 ± 1.7
GF 6965	5-35	55.4 ± 1.0	50.2 ± 2.6
GF 6965*	5-35 Direct Aspiration	49.1 ± 1.5	
GF 6966	5-33	40.8 ± 0.8	37.2 ± 2.4
GF 6967	5-32	56.1 ± 0.7	59.4 ± 3.6
GF 6968	5-30	44.9 ± 1.0	41.5 ± 2.6
GF 6969	5-28	78.3 ± 1.8	79.0 ± 3.1
GF 6969*	5-28 Direct Aspiration	81.3 ± 2.0	

*Direct Aspiration Atomic Absorption Data

A sample of NBS bovine liver was also analyzed with these samples. These results are expressed as μg Pb/gram of SRM.

Contractor Code	NBS Code	Contractor Result	NBS Certified Value
GF 6970	SRM 1577	0.33 ± 0.04	0.34 ± 0.08

these two interlaboratory comparisions between the Contractor and the reference laboratories of EPA and CDC, it can be concluded that the accuracy data generated by the internal quality control program of the Contractor provide a valid assessment of the quality of the analytical data produced under this contract.

4. Blind Sample Split Analyses--A large portion of the internal analytical quality control program encompassed blind split sample analysis of hair, blood, and urine. A measure of the statistical profile of these data is the coefficient of variation for the split sample pairs. Complete data for this phase of the contract effort are appended. Comparative precision data for the appropriate type of composite control sample and the mean value for the actual sample splits are contained in Table 17. If all pertinent criteria for effective quality control have been satisfied, the Coefficient of Variation should be approximately equal for the control samples and the actual sample splits.

   An analysis of the data immediately indicates that some phase of the program is "out of control." The final segment of this report section is devoted to an assessment of the internal analytical quality control program and related ramifications.

5. Assessment of Analytical Quality Control Program--A quality control program in the laboratory has two primary functions. First, the program should monitor the reliability of the results

TABLE 17. Coefficient of Variation Comparison for Control Samples and Mean of Actual Sample Splits.

	V for Control Samples	V for Mean of Actual Sample Splits
Hair		
Lead	5.98%	15.2%
Cadmium	6.15%	17.5%
Arsenic	5.06%	14.8%
Blood		
Lead	5.98%	22.0%
Copper	3.44%	10.6%
Zinc	1.55%	9.0%
FEP	Not Determined	4.51%
Urine		
Arsenic	5.06%	24.9%

reported. It should continually provide an answer to, "How good are the submitted results?" This phase may be termed "measurement of quality." The second function is the control of quality in order to meet the program requirements for reliability.

The control of analytical performance in the laboratory is based on the assumption that a "valid sample" has been submitted for analysis. A "valid sample" implies that the sample was properly taken, preserved, and delivered to the laboratory in a condition appropriate for all analytical techniques to be employed. Further, the validity of controlled analytical performance is dependent upon the use of currently recognized analytical methods substantiated by the recording and reporting of subsequent laboratory results in a systematic, uniform, and permanent fashion. It must be recognized, however, that quality control begins with the sample collection and does not end until the resulting data are reported. The laboratory control of analytical performance is but one essential link in obtaining reliable data. Each single phase of a quality control effort will only be as good as the poorest, least controlled area which has an effect on the results.

A review of the internal analytical quality control program precision, accuracy, and interlaboratory comparison data on standard samples revealed that all phases of the analytical performance in the laboratory were "under control." Based on the data from the composite hair study and visual observations of

the blood and urine samples as they were received in the laboratory, the "out of control" portion of the project was readily identifiable as the samples themselves. Analytical quality control is based on the assumption that a homogeneous sample, free from obvious external contamination, has been analyzed. All urine samples received for analysis contained varying amounts of precipitate, and many of the blood samples contained macroclots. Hair samples have an inherent variability and cannot be considered homogeneous tissue samples. In addition, the hair samples were extremely small; and most split analyses were performed on samples sizes of 0.25 gm.

When all pertinent factors are considered, it can be concluded that the Coefficients of Variation obtained for the blind sample splits represent sample inhomogeneity rather than the nonreproducibility of precision for the analytical methodology. This conclusion is in no way detrimental to the internal analytical quality control program. It does, in fact, demonstrate that the program was properly designed and conducted since the "out of control" fraction was isolated and identified.

E. Assessment of Analytical Data - The problem of less than ideal samples was readily apparent as soon as the first shipment of samples arrived in the laboratory. Appropriate method modification to minimize the overall effect on the project were suggested by the Contractor and approved by the Project Officer. These modifications were designed to overcome sample shortcomings in all areas except those which were

exclusively dependent on sample homogeneity--specifically, blind sample split precision. An overall assessment of the analytical data for each sample type will now be presented.

1. Hair--With the exception of the samples used in the blind split quality control program, the total hair sample as received was analyzed. The uncertainty of the data obtained from those samples which were analyzed in their entirety (>90%) and not split for quality control, correlates directly to the accuracy and precision of the analytical method as previously presented. The mean value for the blind sample split analyses is the most accurate representation for these samples. This mean value has a comparable accuracy to the samples which were analyzed as a whole.

2. Blood--The situation for blood is identical to that for hair.

3. Dust--All dust samples were analyzed as total sample received. On an absolute basis, the data are as good as the accuracy and precision of the methods employed .

4. Urine--The urine analyses are the least precise data in the entire study. Because of an extreme variation in sample size, it was not analytically feasible to perform the analyses on the total sample as received. The nature and amount of precipitate changed drastically from sample to sample. Every effort was made to remove a representative aliquot for analysis; however, the magnitude of the Coefficient of Variation for the blind sample splits

(24.9%) indicates that the difficulty was not overcome in many cases. While the urine data are less precise on an absolute basis, it should be pointed out that on a relative basis the data are still meaningful for collection site comparisons. For example, the median value for arsenic in urine for site AJ is 9.77 µg/100 ml, for site HA, 3.06 µg/100 ml, and for site PV, 0.49 µg/100 ml. Thus it is apparent that the lack of precision in the urine data definitely does not preclude assessment of the relative significance of the analytical results for the study. It should, however, be pointed out that the validity of specific gravity measurements taken on precipitated samples has not been established.

The measures of accuracy formulated in section D of this report can be applied directly to an evaluation of all data for a given element analyzed in a specific matrix. A summary treatment of the analytical means of each type of determination for the four matrices from various collection sites is shown in Tables 18 through 21. The accuracy of these values, and the individual data from which they were generated, is basically equivalent to that achieved analytically on standard reference materials.

In the past, it has been customary to exclude "less-than" values from chemical analytical data before performing statistical analysis. This is regrettable as the less-than values may reflect the condition of an important subset of the data, and their omission possibly precludes the likelihood that the finished

TABLE 18. Analytical Data Summary - Hair

Concentration units are micrograms per gram

"Range indicated is the mean ± 2 standard deviations"

Collection Site	Lead	Cadmium	Arsenic
AJ	19.2 ± 0.3	2.68 ± 0.08	1.91 ± 0.19
AL	17.5 ± 0.3	0.69 ± 0.02	0.10 ± 0.01
AM	38.4 ± 0.7	4.11 ± 0.12	
AN	25.4 ± 0.5	1.94 ± 0.06	20.3 ± 2.1
AP	23.5 ± 0.4	2.22 ± 0.06	0.48 ± 0.05
BV	56.7 ± 1.	9.14 ± 0.26	
BX	170. ± 3.	7.94 ± 0.23	
CC	45.8 ± 0.8	2.78 ± 0.08	
CH	22.8 ± 0.4	2.80 ± 0.08	0.14 ± 0.02
DO	26.7 ± 0.5	1.88 ± 0.05	0.43 ± 0.04
GL	51.1 ± 0.9	6.35 ± 0.18	
HA	26.4 ± 0.5	1.81 ± 0.05	2.09 ± 0.21
HK	64.0 ± 1.	4.26 ± 0.12	
HL	20.4 ± 0.4	1.65 ± 0.05	0.18 ± 0.02
MG	15.9 ± 0.3	1.33 ± 0.04	0.37 ± 0.04
MI	31.7 ± 0.6	1.90 ± 0.06	0.47 ± 0.05
MN	20.4 ± 0.4	2.13 ± 0.06	
MO	17.6 ± 0.3	1.96 ± 0.06	0.31 ± 0.03
NG	15.9 ± 0.3	1.29 ± 0.04	0.41 ± 0.04
PL	44.4 ± 0.8	7.40 ± 0.21	
PV	12.6 ± 0.2	1.18 ± 0.03	0.09 ± 0.01
SA	11.9 ± 0.2	1.09 ± 0.03	0.10 ± 0.01
SM	19.3 ± 0.3	1.26 ± 0.04	0.23 ± 0.02
WP	13.9 ± 0.3	1.84 ± 0.05	0.43 ± 0.04
All Sites	29.3 ± 0.5	2.95 ± 0.08	2.14 ± 0.22
Number of Positive Results	1577	1451	1126

TABLE 19. Analytical Data Summary - Blood

Concentrations are μg/100 ml whole blood

"Range indicated is the mean ± 2 standard deviations"

Collection Site	FEP	Lead	Cadmium	Copper	Zinc
AJ	22.1 ± 1.7	12.5 ± 2.0		105. ± 7.	372. ± 18.
AL	26.1 ± 2.0	17.7 ± 2.8	0.21 ± 0.03	99.4 ± 7.	368. ± 18.
AM	28.8 ± 2.2	22.7 ± 3.6	0.12 ± 0.02		371. ± 18.
AN	26.8 ± 2.1	13.4 ± 2.1		90.3 ± 6.	372. ± 18.
AP	35.8 ± 2.8	19.6 ± 3.1		95.7 ± 6.	320. ± 16.
BV	26.5 ± 2.1	28.9 ± 4.6	0.51 ± 0.07		552. ± 27.
BX	33.9 ± 2.6	13.7 ± 2.2	0.12 ± 0.02		
CC	28.6 ± 2.2	19.6 ± 3.1	0.16 ± 0.02		295. ± 15.
CH	18.5 ± 1.4	16.5 ± 2.6		97.7 ± 6.	346. ± 17.
DO	30.0 ± 2.3	20.5 ± 3.3		94.6 ± 6.	339. ± 17.
GL	22.2 ± 1.7	12.6 ± 2.0	0.16 ± 0.02		
HA	30.4 ± 2.4	21.2 ± 3.4		152. ± 10.	521. ± 26.
HK	26.8 ± 2.1	18.8 ± 3.0	0.32 ± 0.05		
HL	34.1 ± 2.7	17.1 ± 2.7		75.5 ± 5.	383. ± 19.
MG	19.4 ± 1.5	9.1 ± 1.5		96.6 ± 6.	352. ± 17.
MI	27.3 ± 2.1	17.3 ± 2.8		126. ± 8.	424. ± 21.
MN	25.9 ± 2.0	14.8 ± 2.4	0.22 ± 0.03		351. ± 17.
MO	23.8 ± 1.8	13.9 ± 2.2		106. ± 7.	340. ± 17.
NG	37.0 ± 2.9	15.3 ± 2.4	0.29 ± 0.04	104. ± 7.	352. ± 17.
PL	35.6 ± 2.7	17.9 ± 2.9	0.37 ± 0.05		362. ± 18.
PV	21.0 ± 1.6	16.9 ± 2.7	0.24 ± 0.03	92.7 ± 6.	372. ± 18.
SA	23.1 ± 1.8	15.2 ± 2.4	0.18 ± 0.03	78.1 ± 5.	346. ± 17.
SM	23.8 ± 1.9	18.0 ± 2.9		106. ± 7.	362. ± 18.
WP	17.3 ± 1.3	18.6 ± 3.0		106. ± 7.	374. ± 18.
All Sites	27.1 ± 2.1	17.5 ± 2.8	0.26 ± 0.04	103. ± 7.	379. ± 19.
Number of Positive Results	1941	1921	844	1392	1762

TABLE 20. Analytical Data Summary - Dust

Concentrations are absolute micrograms per towelette

"Range indicated is the mean ± 2 standard deviations"

Collection Site	Lead	Cadmium	Arsenic	Copper	Zinc
AJ	44.2 ± 0.8	1.73 ± 0.05	3.97 ± 0.4	128. ± 1.5	260. ± 2.
AL	17.7 ± 0.4	0.88 ± 0.03	0.09 ± 0.009	559. ± 6.	96.6 ± 0.7
AM	35.9 ± 0.6	1.50 ± 0.04	0.50 ± 0.05	423. ± 5.	241. ± 1.8
AN	45.2 ± 0.8	2.22 ± 0.06	34.2 ± 3.4	122. ± 1.4	111. ± 0.8
AP	48.4 ± 0.9	1.34 ± 0.04	1.18 ± 0.12	123 ± 1.4	89.7 ± 0.7
BV	76.2 ± 1.4	8.64 ± 0.25	0.77 ± 0.08	17.6 ± 0.2	546. ± 4.
BX	293. ± 5.3	0.49 ± 0.01	0.27 ± 0.03	2.14 ± 0.03	114. ± 0.9
CC					
CH	82.5 ± 1.5	1.74 ± 0.05	0.40 ± 0.04	78.1 ± 0.9	149. ± 1.1
DO	142. ± 2.6	2.86 ± 0.08	3.67 ± 0.37	462. ± 5.4	192. ± 1.5
GL	37.5 ± 0.7	0.71 ± 0.02	0.09 ± 0.009	123. ± 1.4	43.8 ± 0.33
HA	56.4 ± 1.0	2.35 ± 0.07	8.93 ± 0.9	709. ± 8.	471. ± 4.
HK	81.0 ± 1.5	1.18 ± 0.03	0.12 ± 0.01	1023 ± 12.	179. ± 1.4
HL	44.1 ± 0.8	0.61 ± 0.02	0.27 ± 0.03	408. ± 5.	50.2 ± 0.38
MG	17.4 ± 0.3	0.82 ± 0.02	0.91 ± 0.09	56.9 ± 0.7	39.3 ± 0.30
MI	19.6 ± 0.4	0.85 ± 0.02	0.56 ± 0.06	107. ± 1.2	110. ± 0.83
MN					
MO	22.2 ± 0.4	1.51 ± 0.04	0.41 ± 0.04	158. ± 1.8	275. ± 2.
NG	37.4 ± 0.7	0.92 ± 0.03	1.43 ± 0.14	63.2 ± 0.7	98.3 ± 0.7
PL	86.1 ± 1.6	10.3 ± 0.30	2.35 ± 0.24	140. ± 1.6	1616. ± 12.
PV	25.2 ± 0.5	1.23 ± 0.04	0.15 ± 0.02	2.73 ± 0.03	60.0 ± 0.5
SA	24.1 ± 0.4	1.14 ± 0.03	0.31 ± 0.03	21.3 ± 0.25	145. ± 1.1
SM	25.5 ± 0.5	0.42 ± 0.01	0.41 ± 0.04	35.3 ± 0.41	40.7 ± 0.3
WP	50.2 ± 0.9	1.51 ± 0.04	0.44 ± 0.04	1784. ± 21.	434. ± 3.
All Sites	59.8 ± 1.1	2.10 ± 0.06	2.87 ± 0.29	295. ± 3.	247. ± 2.
Number of Positive Results	220	220	214	220	219

TABLE 21. Analytical Data Summary - Urine

Concentrations are micrograms As/100 ml

Collection Sites	Mean Coefficient of Variation	Mean Value	Uncertainty* Calculated Using	
			Actual Site V	Mean V for Project
AJ	10.8%	11.53	± 2.5	± 5.7
AL	30.6%	1.33	± 0.8	± 0.7
AN	12.3%	3.82	± 0.9	± 1.9
AP	24.7%	2.19	± 1.1	± 1.1
CH	10.5%	2.19	± 0.5	± 1.1
DO	38.2%	2.75	± 2.1	± 1.4
HA	16.5%	3.81	± 1.3	± 1.9
HL	33.5%	1.19	± 0.5	± 0.6
MG	22.8%	2.41	± 1.1	± 1.2
MI	15.4%	2.53	± 0.8	± 1.3
MO	3.9%	2.28	± 0.2	± 1.1
NG	16.9%	2.30	± 0.8	± 1.1
PV	61.9%	1.34	± 1.7	± 0.7
SA	43.5%	1.90	± 1.7	± 0.9
SM	27.7%	2.80	± 1.6	± 1.4
WP	20.7%	2.50	± 1.0	± 1.2
All Sites	24.9%	3.07		± 1.5
Number of Positive Results	1034			

*Uncertainty measurements indicate tolerance limits of ± two standard deviations.

statistics are representative of the population from which the samples were taken. A technique exists for working with data having less-thans all of the same value (i.e. truncated data), but no technique has been established for analyzing data having variable less-thans.

If all less-thans are considered to be in fact zero, a mean taken from the data is a low bound on all possible means that may be taken from the data by any technique. Similarly, if the less--thans are considered positive at the value stated for the less-than value, a high bound on the mean may be set. The mean best fitting the data must lie between these two extremes.

The data in Tables 18-22 have been treated in the customary manner. A comparison of the means determined from consideration of only positive results and the means determined by the high and low bounds on these groups of data in which less-than values appeared is contained in Table 22. For most of the data from this study, the calculation of a mean from only positive results produces very little alteration of the population representation.

TABLE 22. Mean Ranges of Groups Containing Less-than Values

Collection Site	Sample Type	Element	Mean of Positives	Mean High Bound	Mean Low Bound
AJ	Hair	Cd	2.684	2.660	2.653
AJ	Hair	Pb	19.185	18.850	18.739
AL	Dust	As	0.090	0.077	0.072
AL	Hair	As	0.096	0.089	0.083
AL	Hair	Cd	0.690	0.486	0.390
AL	Urine	As	1.328	1.231	1.223
AM	Blood	Cd	0.120	0.117	0.115
AM	Hair	Cd	4.118	3.562	3.501
AN	Hair	Cd	1.943	1.868	1.854
AP	Hair	As	0.477	0.467	0.464
AP	Hair	Cd	2.224	2.030	1.983
AP	Hair	Pb	23.450	23.202	23.133
AP	Urine	As	2.187	2.131	2.129
BV	Blood	Cd	0.508	0.502	0.501
BV	Blood	Pb	28.909	28.624	28.577
BX	Dust	As	0.271	0.222	0.217
CC	Hair	Cd	2.779	2.536	2.486
CH	Hair	As	0.144	0.139	0.133
CH	Hair	Cd	2.803	2.718	2.712
CH	Urine	As	2.185	2.057	2.051
DO	Hair	As	0.430	0.426	0.425
DO	Hair	Cd	1.876	1.733	1.699
DO	Hair	Pb	26.739	25.985	25.895
GL	Blood	Pb	12.559	12.091	12.013
GL	Dust	As	0.094	0.087	0.084
GL	Dust	Zn	43.817	39.443	39.436
GL	Hair	Pb	51.161	49.636	49.456
HA	Hair	As	2.086	2.066	2.066
HA	Urine	As	3.812	3.723	3.721
HK	Dust	As	0.117	0.108	0.105
HL	Hair	As	0.183	0.174	0.169
HL	Hair	Cd	1.647	1.474	1.437
HL	Urine	As	1.193	1.135	1.130
MG	Hair	As	0.369	0.357	0.354
MG	Hair	Cd	1.330	0.860	0.679

TABLE 22. Mean Ranges of Groups Containing Less-than Values (con't)

Collection Site	Sample Type	Element	Mean of Positives	Mean High Bound	Mean Low Bound
MG	Hair	Pb	15.888	14.570	14.197
MI	Urine	As	2.531	2.463	2.461
MN	Blood	Cd	0.223	0.220	0.220
MO	Urine	As	2.281	2.252	2.251
NG	Hair	As	0.410	0.391	0.385
NG	Hair	Cd	1.289	0.878	0.664
NG	Hair	Pb	15.922	15.393	15.209
NG	Urine	As	2.301	2.208	2.204
PL	Hair	Cd	7.389	7.294	7.289
PV	Dust	As	0.154	0.128	0.123
PV	Hair	As	0.092	0.082	0.075
PV	Hair	Cd	1.176	1.049	1.026
PV	Urine	As	1.340	1.049	1.025
SA	Hair	As	0.100	0.100	0.096
SA	Hair	Cd	0.092	0.972	0.945
SA	Hair	Pb	11.861	11.672	11.633
SA	Urine	As	1.902	1.728	1.718
SM	Hair	As	0.228	0.189	0.163
SM	Hair	Cd	1.262	0.990	0.811
SM	Hair	Pb	19.318	15.182	13.799
WP	Hair	As	0.428	0.419	0.417
WP	Hair	Cd	1.844	1.574	1.525
WP	Hair	Pb	13.907	13.348	13.220
WP	Urine	As	2.502	2.462	2.460

APPENDIX

APPENDIX - QUALITY CONTROL

FEP

BLOOD

QC SAMPLE	FEP CONC.	COMP. SAMPLE	FEP CONC.	MEAN	COEFFICIENT OF VARIATION (%)	SELP
1244	11.5	QF3989	13.1	12.3	3.48	(5)
1260	17.5	QF4001	17.2	17.4	0.95	(5)
1261	26.5	QF4017	26.5	26.5	0	(5)
1262	11.3	QF4029	9.98	10.6	11.9	(6)
1263	25.7	QF4041	25.4	25.5	0.84	(5)
1264	24.7	QF4053	24.5	24.6	0.65	(5)
1265	23.0	QF4071	25.2	24.1	4.60	(5)
1266	24.5	QF4083	24.4	24.5	1.10	(5)
1267	34.4	QF4101	34.0	34.2	1.38	(5)
1268	19.0	QF4113	19.0	19.0	0	(5)
1304	25.3	QF4125	25.0	25.2	1.90	(5)
1305	13.6	QF4143	14.1	13.9	1.19	(5)
1306	16.5	QF4161	17.0	16.8	0.70	(5)
1307	24.0	QF4179	22.7	23.4	4.12	(5)
1308	14.7	QF4203	14.7	14.7	4.88	(5)
1314	15.4	QF4215	16.2	15.8	1.00	(5)
1315	18.1	QF4233	17.9	18.0	0.82	(5)
1316	14.0	QF2811	13.1	13.5	5.05	(5)
1317	18.1	QF2802	18.6	18.4	1.40	(5)
1318	24.5	QF2817	25.1	24.8	1.14	(5)
1319	23.4	QF2835	24.9	24.2	1.24	(5)
1320	13.1	QF2847	12.5	12.8	4.31	(5)
1321	10.8	QF2859	10.4	10.6	1.85	(5)
1322	24.8	QF2871	26.0	25.4	3.19	(5)
1323	14.4	QF2890	13.8	14.1	3.19	(5)
1324	24.5	QF2907	24.5	24.5	4.20	(5)
1325	10.4	QF2931	14.4	12.4	10.11	(5)
1326	14.1	QF2943	14.9	14.5	2.24	(5)
1327	19.4	QF2955	20.1	19.8	1.70	(5)
1328	40.8	QF2967	41.7	41.3	0.22	(5)
1329	17.1	QF2980	16.8	17.0	1.99	(5)
1330	15.9	QF2991	16.1	16.0	1.91	(5)
1331	18.4	QF3011	18.1	18.3	1.45	(5)
1332	26.4	QF3071	26.4	26.4	0	(5)
1333	25.0	QF3059	27.0	26.0	1.52	(5)
1334	24.1	QF3071	23.7	23.9	1.40	(5)
1335	10.2	QF3089	11.0	10.6	5.52	(5)
1336	14.9	QF3101	14.9	14.9	0	(5)
1337	28.0	QF3119	28.5	28.3	4.00	(5)
1338	17.0	QF3137	18.0	17.5	5.66	(5)
1339	15.6	QF3149	21.0	18.3	9.61	(5)
1340	17.7	QF3167	18.	17.9	1.11	(5)
1341	14.3	QF3179	15.7	15.0	1.97	(5)
1342	0.4	QF3191	0.	0.2	1.41	(5)
1343	0.2	QF4077	0.2	0.2	0.00	(5)

APPENDIX - (UNAUDITED - CONTINUED)

FEP

BLOOD

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UC SAMPLE	FEP CONC.	COMP. SAMPLE	FEP CONC.	[illegible]	[illegible]	[illegible]
1421	1.7	GF4083	15.2	[illegible]	[illegible]	[illegible]
1422	17.1	GF4240	20.4	[illegible]	[illegible]	[illegible]
1423	13.0	GF4047	17.5	[illegible]	[illegible]	[illegible]
1424	18.0	GF4039	18.7	[illegible]	[illegible]	[illegible]
1425	44.1	GF4903	43.6	[illegible]	[illegible]	[illegible]
1426	10.7	GF4411	21.1	[illegible]	[illegible]	[illegible]
1427	14.1	GF4421	[illegible]	[illegible]	[illegible]	[illegible]
1428	13.9	GF4971	[illegible]	[illegible]	[illegible]	[illegible]
1429	[illegible]	GF4430	[illegible]	[illegible]	[illegible]	[illegible]
1430	14.9	GF4951	[illegible]	[illegible]	[illegible]	[illegible]
1431	[illegible]	GF4954	[illegible]	[illegible]	[illegible]	[illegible]
1432	[illegible]	GF4404	[illegible]	[illegible]	[illegible]	[illegible]
1433	[illegible]	GF4970	[illegible]	[illegible]	[illegible]	[illegible]
1434	[illegible]	GF4941	[illegible]	[illegible]	[illegible]	[illegible]
1435	[illegible]	GF4996	[illegible]	[illegible]	[illegible]	[illegible]
1436	[illegible]	GF5004	[illegible]	[illegible]	[illegible]	[illegible]
1437	[illegible]	GF5007	[illegible]	[illegible]	[illegible]	[illegible]
1438	[illegible]	GF5014	[illegible]	[illegible]	[illegible]	[illegible]
1439	[illegible]	GF5011	[illegible]	[illegible]	[illegible]	[illegible]
1440	[illegible]	GF5054	[illegible]	[illegible]	[illegible]	[illegible]
1545	[illegible]	GF5179	[illegible]	[illegible]	[illegible]	[illegible]
1547	[illegible]	GF5171	[illegible]	[illegible]	[illegible]	[illegible]
1548	[illegible]	GF5174	[illegible]	[illegible]	[illegible]	[illegible]
1549	[illegible]	GF5137	[illegible]	[illegible]	[illegible]	[illegible]
1550	[illegible]	GF5181	[illegible]	[illegible]	[illegible]	[illegible]
1551	[illegible]	GF5113	[illegible]	[illegible]	[illegible]	[illegible]
1552	[illegible]	GF5115	[illegible]	[illegible]	[illegible]	[illegible]
1553	[illegible]	GF5145	[illegible]	[illegible]	[illegible]	[illegible]
1554	[illegible]	GF5156	[illegible]	[illegible]	[illegible]	[illegible]
1555	[illegible]	GF5154	[illegible]	[illegible]	[illegible]	[illegible]
1556	[illegible]	GF5158	[illegible]	[illegible]	[illegible]	[illegible]
1657	[illegible]	GF5245	[illegible]	[illegible]	[illegible]	[illegible]
1658	[illegible]	GF5240	[illegible]	[illegible]	[illegible]	[illegible]
1659	[illegible]	GF5241	[illegible]	[illegible]	[illegible]	[illegible]
1660	[illegible]	GF5214	[illegible]	[illegible]	[illegible]	[illegible]
1661	[illegible]	GF5215	[illegible]	[illegible]	[illegible]	[illegible]
1662	[illegible]	GF5218	[illegible]	[illegible]	[illegible]	[illegible]
1663	[illegible]	GF5245	[illegible]	[illegible]	[illegible]	[illegible]
1664	[illegible]	GF5240	[illegible]	[illegible]	[illegible]	[illegible]
1665	[illegible]	GF5250	[illegible]	[illegible]	[illegible]	[illegible]
1666	[illegible]	GF5275	[illegible]	[illegible]	[illegible]	[illegible]
1667	[illegible]	GF5218	[illegible]	[illegible]	[illegible]	[illegible]
1668	[illegible]	GF5245	[illegible]	[illegible]	[illegible]	[illegible]
1669	[illegible]	GF5205	[illegible]	[illegible]	[illegible]	[illegible]
1670	[illegible]	GF5215	[illegible]	[illegible]	[illegible]	[illegible]
1671	[illegible]	GF5216	[illegible]	[illegible]	[illegible]	[illegible]
1672	[illegible]	GF5214	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX - QUALITY CONTROL

FEF

BLOOD

SAMPLE	FEF CONF.	CONF.SAMPLE	FEF CONF.	MEAN	COEFFICIENT OF VARIATION %	FAILED
[illegible]						

APPENDIX - QUALITY CONTROL

FEP

BLOOD

QC SAMPLE	FP CONC.	CORR.SAMPLE	FP CONC.	MEAN	COEFFICIENT OF VARIATION%	SPLIT
1716	17.0	QF7122	14.8	14.9	1.21	AP
1717	14.7	QF7123	15.0	14.1	2.74	NG
1718	13.2	QF7141	20.8	22.0	3.04	NG
1719	41.0	QF7152	41.8	42.3	2.09	NG
1720	29.8	QF7153	29.1	29.4	0.60	NG
1721	22.0	QF7174	21.2	22.1	4.91	NG
1722	17.3	QF7175	17.6	18.4	2.22	NG
1723	6.8	QF7176	6.4	6.1	1.80	NG
1724	18.4	QF7177	17.5	18.1	3.04	NG
1725	15.3	QF7178	14.6	14.1	1.99	NG
1726	21.0	QF7179	21.0	21.1	2.67	NG
1727	20.8	QF7180	20.2	20.1	1.30	NG
1728	31.4	QF7181	30.1	31.1	4.61	NG
1729	30.8	QF7182	31.4	31.1	1.11	NG
1730	19.2	QF7183	19.7	19.1	1.34	NG
1731	19.4	QF7184	20.2	20.1	1.48	NG
1732	21.4	QF7185	20.6	21.1	2.50	NG
1733	20.1	QF7186	20.8	20.1	4.82	NG
1734	14.0	QF7187	14.0	14.1	0	NG
1735	21.4	QF7188	21.4	21.1	5.67	NG
1736	50.4	QF7189	50.4	51.1	1.81	NG
1737	20.1	QF7190	20.1	21.1	0	NG
1738	13.4	QF7191	13.4	13.1	1.73	NG
1739	18.1	QF7192	18.1	18.1	0	NG
1740	14.1	QF7193	14.1	14.1	0.81	NG
1741	18.8	QF7194	14.8	14.1	0	NG
1742	14.1	QF7195	14.1	14.1	1.41	NG
1743	41.0	QF7196	41.0	41.1	0.84	NG
1744	19.0	QF7197	19.0	19.1	0.84	NG
1745	14.1	QF7198	14.1	14.1	1.73	NG
1746	21.5	QF7199	21.6	21.1	4.43	NG
1747	21.5	QF7200	22.4	22.1	4.47	NG
1748	21.1	QF7201	21.1	21.1	0	NG

APPENDIX - QUALITY CONTROL

LEAD

BLOOD

QC SAMPLE	PB CONC.	COPP.SAMPLE	PB CONC.	[illegible]	[illegible] CONCENTRATION (%)	SALTS
[illegible]	40.1	GF2502	37.3	41.7	14.8	HI
[illegible]	17.7	GF2529	18.1	[illegible]	[illegible]	HI
[illegible]	10.5	GF2542	36.4	40.4	12.5	HI
[illegible]	18.6	GF2564	14.2	16.5	18.2	HI
[illegible]	15.1	GF2575	12.8	13.4	11.4	HI
[illegible]	27.9	GF2580	9.07	10.5	73.0	HI
[illegible]	13.1	GF2598	14.1	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4064	[illegible]	4.44	[illegible]	HI
[illegible]	9.89	GF4077	10.5	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4083	9.22	[illegible]	[illegible]	HI
[illegible]	7.26	GF4090	14.3	10.8	[illegible]	HI
[illegible]	[illegible]	GF4097	16.7	[illegible]	[illegible]	HI
[illegible]	7.04	GF4099	11.8	[illegible]	[illegible]	HI
[illegible]	10.6	GF4903	18.1	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4913	[illegible]	[illegible]	[illegible]	HI
[illegible]	18.3	GF4931	5.32	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4933	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4938	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4951	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4954	[illegible]	[illegible]	[illegible]	HI
[illegible]	26.1	GF4969	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4978	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4990	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF4998	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF5004	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF5007	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF5014	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF5052	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF5054	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2601	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2609	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2611	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2615	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2622	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2627	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2631	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2655	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2658	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2660	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2678	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2680	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2695	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2707	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2709	[illegible]	[illegible]	[illegible]	HI
[illegible]	[illegible]	GF2754	[illegible]	[illegible]	[illegible]	HI

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APPENDIX - QUALITY CONTROL

LEAD

BLOOD

QC SAMPLE	Pb CONC.	CORR. SAMPLE	Pb CONC.	RATIO	CORRELATION %	NOTE
1461	20.0	QF1461	18.4	1.09	91	
1462	10.3	QF1462	11.0	.94	88	
1463	17.7	QF1463	21.5	.82	77	
1464	7.1	QF1464	20.1	.35	99	
1465	11.1	QF1465	18.4	.60	94	
1504	20.2	QF1504	19.2	1.05	97	
1505	14.6	QF1505	13.4	1.09	97	
1506	14.8	QF1506	14.4	1.03	97	
1507	14.8	QF1507	14.4	1.03	97	
1508	14.8	QF1508	14.4	1.03	97	
1509	14.8	QF1509	14.4	1.03	97	
1510	11.0	QF1510	10.7	1.03	97	
1511	11.3	QF1511	10.3	1.10	97	
1512	10.3	QF1512	10.3	1.00	97	
1513	10.3	QF1513	10.3	1.00	97	
1514	14.4	QF1514	10.3	1.40	97	
1515	14.4	QF1515	10.3	1.40	97	
1516	7.2	QF1516	6.9	1.04	97	
1517	13.9	QF1517	13.8	1.01	97	
1518	13.1	QF1518	13.1	1.00	97	
1519	13.1	QF1519	13.1	1.00	97	
1520	13.1	QF1520	13.1	1.00	97	
1521	13.9	QF1521	13.8	1.01	97	
1522	14.1	QF1522	13.8	1.02	97	
1523	14.8	QF1523	14.4	1.03	97	
1524	14.8	QF1524	14.4	1.03	97	
1525	14.8	QF1525	14.4	1.03	97	
1526	14.8	QF1526	14.4	1.03	97	
1527	14.8	QF1527	14.4	1.03	97	
1528	14.8	QF1528	14.4	1.03	97	
1529	14.8	QF1529	14.4	1.03	97	
1530	14.8	QF1530	14.4	1.03	97	
1531	14.8	QF1531	14.4	1.03	97	
1532	14.8	QF1532	14.4	1.03	97	
1533	14.8	QF1533	14.4	1.03	97	
1534	14.8	QF1534	14.4	1.03	97	
1535	14.8	QF1535	14.4	1.03	97	
1536	14.8	QF1536	14.4	1.03	97	
1537	14.8	QF1537	14.4	1.03	97	
1538	14.8	QF1538	14.4	1.03	97	
1539	14.8	QF1539	14.4	1.03	97	
1540	14.8	QF1540	14.4	1.03	97	
1541	14.8	QF1541	14.4	1.03	97	
1542	14.8	QF1542	14.4	1.03	97	
1543	14.8	QF1543	14.4	1.03	97	
1544	14.8	QF1544	14.4	1.03	97	
1545	14.8	QF1545	14.4	1.03	97	
1546	14.8	QF1546	14.4	1.03	97	
1547	14.8	QF1547	14.4	1.03	97	
1548	14.8	QF1548	14.4	1.03	97	
1549	14.8	QF1549	14.4	1.03	97	
1550	14.8	QF1550	14.4	1.03	97	
1551	14.8	QF1551	14.4	1.03	97	
1552	14.8	QF1552	14.4	1.03	97	
1553	14.8	QF1553	14.4	1.03	97	
1554	14.8	QF1554	14.4	1.03	97	
1555	14.8	QF1555	14.4	1.03	97	
1556	14.8	QF1556	14.4	1.03	97	
1557	14.8	QF1557	14.4	1.03	97	
1558	14.8	QF1558	14.4	1.03	97	
1559	14.8	QF1559	14.4	1.03	97	
1560	14.8	QF1560	14.4	1.03	97	
1561	14.8	QF1561	14.4	1.03	97	
1562	14.8	QF1562	14.4	1.03	97	
1563	14.8	QF1563	14.4	1.03	97	
1564	14.8	QF1564	14.4	1.03	97	
1565	14.8	QF1565	14.4	1.03	97	
1566	14.8	QF1566	14.4	1.03	97	
1567	14.8	QF1567	14.4	1.03	97	
1568	14.8	QF1568	14.4	1.03	97	
1569	14.8	QF1569	14.4	1.03	97	
1570	14.8	QF1570	14.4	1.03	97	
1571	14.8	QF1571	14.4	1.03	97	
1572	14.8	QF1572	14.4	1.03	97	
1573	14.8	QF1573	14.4	1.03	97	
1574	14.8	QF1574	14.4	1.03	97	
1575	14.8	QF1575	14.4	1.03	97	
1576	14.8	QF1576	14.4	1.03	97	
1577	14.8	QF1577	14.4	1.03	97	
1578	14.8	QF1578	14.4	1.03	97	
1579	14.8	QF1579	14.4	1.03	97	
1580	14.8	QF1580	14.4	1.03	97	
1581	14.8	QF1581	14.4	1.03	97	
1582	14.8	QF1582	14.4	1.03	97	
1583	14.8	QF1583	14.4	1.03	97	
1584	14.8	QF1584	14.4	1.03	97	
1585	14.8	QF1585	14.4	1.03	97	
1586	14.8	QF1586	14.4	1.03	97	
1587	14.8	QF1587	14.4	1.03	97	
1588	14.8	QF1588	14.4	1.03	97	
1589	14.8	QF1589	14.4	1.03	97	
1590	14.8	QF1590	14.4	1.03	97	
1591	14.8	QF1591	14.4	1.03	97	
1592	14.8	QF1592	14.4	1.03	97	
1593	14.8	QF1593	14.4	1.03	97	
1594	14.8	QF1594	14.4	1.03	97	
1595	14.8	QF1595	14.4	1.03	97	
1596	14.8	QF1596	14.4	1.03	97	
1597	14.8	QF1597	14.4	1.03	97	
1598	14.8	QF1598	14.4	1.03	97	
1599	14.8	QF1599	14.4	1.03	97	
1600	14.8	QF1600	14.4	1.03	97	

APPENDIX - QUALITY CONTROL

LEAD

BLOOD

QC SAMPLE	PB CONC.	COMP.SAMPLE	PB CONC.	MEAN	COEFFICIENT OF VARIATION %	SPLIT?
560	14.0	QF5935	12.4	13.2	12.3	NO
569	14.7	QF6005	20.1	17.4	1.07	NO
570	16.9	QF6015	18.2	17.6	9.65	NO
571	23.5	QF6025	22.9	23.2	1.90	NO
572	20.4	QF6034	21.1	20.7	1.56	NO
573	21.8	QF6045	24.7	23.2	1.77	NO
574	14.1	QF4135	9.68	11.9	28.2	NO
575	20.6	QF4201	11.1	15.8	40.1	NO
576	14.3	QF4205	8.05	11.2	57.2	NO
581	17.0	QF4219	9.41	13.2	40.5	NO
582	14.7	QF4231	14.2	14.4	2.0	NO
583	19.4	QF4241	14.8	17.1	19.9	NO
584	20.7	QF4247	16.1	18.4	20.8	NO
611	10.9	QF3936	9.67	10.	10.5	NO
612	17.5	QF3957	14.3	15.9	14.3	NO
613	3.07	QF4007	4.13	3.60	50.1	NO
614	4.80	QF4017	10.1	7.47	1.45	NO
621	11.6	QF4027	7.17	9.39	33.1	NO
622	21.8	QF4033	18.7	20.2	10.5	NO
623	17.9	QF4046	13.1	15.5	0.41	NO
624	18.0	QF4050	13.9	15.9	11.8	NO
628	11.0	QF4068	8.91	10.0	14.6	NO
631	15.9	QF4070	12.1	14.0	4.33	NO
632	19.3	QF6142	14.4	16.	4.01	NO
638	4.80	QF6151	7.4*	6.1	19.7	NO
639	10.0	QF6161	9.12	9.6	13.4	NO
640	11.2	QF6171	13.1	12.2	9.74	NO
641	13.7	QF6181	10.7	12.2	1.43	NO
642	10.1	QF6192	16.	13.1	14.1	NO
643	16.2	QF6202	12.7	14.5	14.4	NO
644	13.9	QF6212	15.1	14.5	4.17	NO
645	5.40	QF6218	4.8*	5.1	11.3	NO
646	14.7	QF6228	14.*	14.	11.3	NO
647	11.0	QF6238	9.8*	10.	11.1	NO
648	12.2	QF6249	12.1	12.	0.83	NO
649	11.9	QF6259	10.1	11.	10.4	NO
650	11.2	QF6269	12.2	11.7	10.4	NO
654	7.30	QF6278	14.9	11.	44.1	NO
655	11.1	QF6288	11.	11.	0.0	NO
661	14.2	QF6297	12.	13.	11.	NO
662	11.4	QF6307	10.7	11.	4.7	NO
663	14.0	QF6317	11.7	12.9	12.1	NO
669	11.1	QF6327	11.	11.	0.0	NO
670	10.1	QF6337	12.	11.	11.	NO
671	9.2	QF6347	12.	10.	19.	NO

APPENDIX - SPLIT SAMPLES

ZINC

BLOOD

SAMPLE	IN CONC.	CORR.SAMPLE	IN CONC.	MEAN	COEFFICIENT OF VARIATION %	FILTER
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX - QUALITY CONTROL

LEAD

BLOOD

QC SAMPLE	PB CONC.	COFF.SAMPLE	PB CONC.	MEAN	COEFFICIENT OF VARIATION%	SOLTP
P782	14.1	GF7354	22.0	18.	21.1	MU
P783	17.5	GF7365	27.9	23.4	21.0	MU
P784	11.02	GF7375	15.3	11..	44.1	MU
P785	23.1	GF7385	26..	24..	10.1	MU
P786	14.0	GF7395	19.2	16.6	22.3	MU
P787	4.81	GF7406	18.5	14..	41.6	MU
P788	10.1	GF7416	19.9	15.0	46.3	MU
P789	18.6	GF7426	18.3	18.3	11.1	MU
P790	13.3	GF7436	17.1	15..	10..	MU
P791	16.2	GF7441	22.0	19.1	12..	MU
P792	10.4	GF7452	20.1	15.	44.7	ML
P793	2.93	GF7461	8.79	5..	70.1	ML
P794	10.6	GF7471	12.1	11.4	9.83	ML
P795	14.4	GF7482	17.5	15..	11..	ML
P796	17.1	GF7492	19.9	18.5	10.2	ML

APPENDIX - QUALITY CONTROL

LEAD

BLOOD

O	SAMPLE	PB CONC.	COMP.SAMPLE	PB CONC.	MEAN	COEFFICIENT OF VARIATION-%	SIGN
	1649	12.1	GF6357	12.0	12.1	0.57	PL
	1650	12.3	GF6367	12.1	12.2	0.85	PL
	1651	17.8	GF6374	20.7	19.2	10.8	NL
	1652	17.3	GF6384	11.5	14.4	28.1	NH
	1653	14.0	GF6394	10.6	12.3	28.9	NH
	1654	24.2	GF6405	23.7	24.0	1.55	HH
	1655	14.7	GF6417	13.7	14.2	4.87	NH
	1656	14.7	GF6427	14.3	14.5	1.30	NH
	1657	14.4	GF6435	13.9	14.2	10.0	NH
	1658	17.5	GF6445	16.8	17.2	17.1	HH
	1659	7.39	GF6454	17.9	12.7	59.6	PL
	1660	12.4	GF6462	13.1	12.8	3.30	NL
	1661	19.1	GF6477	10.8	15.0	34.1	NH
	1662	21.2	GF7032	16.4	20.8	11.4	HH
	1708	11.6	GF7043	11.9	11.8	0.58	NN
	1709	10.7	GF7053	17.6	14.2	34.4	HH
	1710	11.6	GF7063	26.6	19.1	48.7	HH
	1711	12.6	GF7074	10.1	11.4	19.4	NH
	1712	16.4	GF7084	27.4	21.9	40.6	HH
	1713	24.1	GF7094	33.0	28.6	31.0	HH
	1714	10.4	GF7104	30.4	20.4	69.2	PH
	1715	4.44	GF7114	8.85	7.65	39.2	PL
	1716	8.97	GF7122	12.6	10.8	28.6	NL
	1717	10.5	GF7132	18.6	14.6	42.0	HH
	1718	12.3	GF7142	13.1	12.8	3.80	NN
	1719	10.5	GF7152	19.2	14.9	2.64	PH
	1720	4.11	GF7162	14.1	9.13	70.0	PL
	1721	9.60	GF7172	12.5	11.1	124.	NL
	1722	17.2	GF7182	21.0	19.1	14.1	HH
	1723	9.46	GF7192	10.1	9.78	4.19	NL
	1724	17.8	GF7202	23.5	20.6	19.4	HH
	1725	9.88	GF7212	10.4	10.1	7.10	NL
	1726	11.4	GF7222	14.1	12.8	14.0	NH
	1727	10.7	GF7232	11.3	11.0	10.0	NN
	1728	9.24	GF7240	10.1	9.65	14.4	NL
	1729	12.1	GF7250	16.1	14.1	19.7	PH
	1730	7.44	GF7260	21.4	14.4	84.1	PL
	1731	9.03	GF7270	11.8	10.4	18.8	NL
	1732	9.73	GF7281	11.3	10.5	20.1	NL
	1733	9.98	GF7291	10.9	10.4	20.1	NL
	1734	14.0	GF7301	22.4	18.2	19.6	PH
	1735	1.00	GF7312	11.0	6.01	0.51	PL
	1736	0.60	GF7322	11.4	6.00	90.4	PL
	1737	5.95	GF7332	10.1	8.02	41.1	PL
	1738	2.10	GF7342	11.4	6.75	0.51	PL